D. B. Huntley

EXCAVATING MACHINERY

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BY

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To

REVEREND B. F. McDANIEL

AS A TOKEN OF APPRECIATION

AND AFFECTION

THIS VOLUME IS DEDICATED

BY THE

AUTHOR

PREFACE

The basis of this book was a set of notes used in my class room and thence expanded to meet practical needs in the field. In its preparation, I have had in mind not only the engineer and the contractor, but also the farmer, land owner, promoter, and officials charged with the construction of public works. It is believed that their interests would be materially enhanced by familiarity with its contents.

I wish especially to express my appreciation of the advice and assistance rendered me in the preparation of this book by my father, the Reverend B. F. McDaniel, and by Professor Ira O. Baker of the University of Illinois.

I wish to make acknowledgment to the following engineers, contractors and manufacturers who have kindly and generously furnished me with general information, cost data, photographs, cuts, etc.: Hon. S. H. Lea, State Engineer of South Dakota; Hon. George A. Ralph, State Drainage Engineer of Minnesota; Mr. Sam G. Porter, Chief Engineer of the Arkansas Valley Sugar Beet and Irrigated Land Company; The Fellsmere Farm Company; The U. S. Reclamation Service; R. H. and G. A. McWilliams; Mulgrew-Boyce Co.; Pollard & Campbell Dredging Co.; Jacobs Engineering Co.; Thew Automatic Shovel Co.; The Marion Steam Shovel Co.; The Bucyrus Co.; F. C. Austin Drainage Excavator Co.; A. N. Cross; American Steel Dredge Co.; Norbom Engineering Co.; Dix Machine Co.; Baker Mfg. Co.; W. G. Gould; W. A. Colt & Sons; Avery Co.; The Buckeye Traction Ditcher Co.; St. Paul Machinery Mfg. Co.; Western Wheeled Scraper Co.; Austin Mfg. Co.; T. F. Stroud & Co.; The Barron & Cole Co.; The Wilcox Construction Co.; J. D. Adams & Co.; Clinton Construction Co.; The Beaver Land and Irrigation Co.; The Electric Journal; Sawyer & Moulton; American Railway Engineering Association; Toledo Foundry and Machine Co.; The Potter Mfg. Co.; The G. W. Parsons Co.; Lambert Hoisting Engine Co.; Brown Hoisting Machinery Co.; John B. Heim; S. Flory Mfg. Co.; Monighan Machine Co.; Lidgerwood Manufacturing Co.; American Steel Dredge Co.; Noble E. Whitford, Res. Engr., State of New York; Mayer Bros. Co.; Lathrop, Shea & Henwood Co.; and the Sinaloa Land and Water Co.

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INTRODUCTION

SCOPE AND LIMITATIONS OF THIS WORK

As its title indicates, the scope of this book is to describe excavating machinery of various kinds and the uses for which it is devised. During the past decade the development of reclamation work in the western and southern sections of the country by private enterprise and by local, state and national governments, has awakened great and general interest. The rapid extension and improvement of railroad systems and the expansion of great cities by the filling in of adjacent waste lands, and by sanitary and other municipal works, have called for the use of the most efficient machinery. Designers and builders have been stimulated by this demand and many marked improvements have been introduced into present-day machinery for these purposes. The author has endeavored to describe the makes and types of excavators commonly used in all classes of work except marine dredging. He has not attempted to describe or even mention every make of excavator, but every type has been treated in sufficient detail to give a clear idea of its construction and field of work.

The author has been impressed by the careless methods used in the construction and repair of excavators. A new machine is built more in accordance with the forms of previous ones of the same class, rather than in accordance with the demands of the particular piece of work to which it is to be applied. Rule of thumb methods are used instead of original design. In making repairs, it is the general custom to replace the broken parts with new ones exactly like the old ones, or after repeated breaks, to make the weak member a little stronger. This is often blind guesswork, and is expensive both to the contractor and the owner and should be replaced by scientific study and accurate workmanship.

The cost data given have been gathered at the expense of much time and labor from a great variety of sources. They are not intended to be an arbitrary guide for the use of any type of excavator in any stated class of work. The conditions and circumstances attending work of this character are so variable and there are usually so many unforeseen factors which may affect the progress of a job,

that information of this kind can only be *suggestive*. However, the author does not agree with those who make the sweeping statement that all cost data are valueless, or with others who state that such records are of worth only to those who have actually made them up from experience. It must be kept in mind that cost data relating to the operation of excavating machinery not only depend on and vary with the conditions and circumstances attending each piece of work, such as soil, topography and climate, but also largely upon the efficiency with which the excavator is operated. The author knows of many cases where the contractor has lost money on account of incompetent and unreliable operators. However, it is here assumed, as in the operation of any type of machinery, that such labor is employed as will secure average results. The cost data given in this book have been quoted, as far as possible, from operations under normal working conditions. In using the cost data given, the engineer and the contractor are advised to consider thoroughly the peculiar conditions attending the work. The author has been surprised, from practical experience and in the preparation of this book, to find that so few contractors and engineers keep complete, systematic and accurate financial records of their business. In the contractor's office the clerk usually gathers together the checks and receipted bills and makes a rough computation of the cost of the work. On the other hand, the average engineer lays out a piece of work and superintends its construction, but does not give close attention to its cost, losing thereby valuable data for future use. This will probably account for the incompleteness of some of the information of this character given in this book. Every engineer and contractor should keep accurate and complete records of the costs of their work, covering all the details in systematic order.

This book is offered in the spirit of an eminent philosopher who said, "I hold every man a debtor to his profession; from the which, as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereunto."

PART I

SCRAPERS, GRADERS AND SHOVELS

EXCAVATING MACHINERY

CHAPTER I

DRAG AND WHEEL SCRAPERS

1. **Slip Scrapers.**—Where small open shallow ditches, with bottom widths of not less than 3 ft., such as road ditches, are to be constructed, drag or slip scrapers are used. The drag scraper is a steel scoop with a round back and curved bottom. The latter is either provided with runners or reinforced with a sheet of hard steel, known as a "double bottom." Wooden handles are attached to either side near the rear of the scoop and are used by the driver in handling it. A heavy bail serves for the purpose of attaching a team of horses to the scoop. The following table gives the description and cost of the various sizes of the ordinary drag scraper:

No. 1, with runners,	capacity 7 cu. ft.,	weight 95 lb.,	cost $4.50
No. 2, with runners,	capacity 5 cu. ft.,	weight 85 lb.,	cost 4.25
No. 3, with runners,	capacity 3½ cu. ft.,	weight 75 lb.,	cost 4.00
No. 1, with double bottom,	capacity 7 cu. ft.,	weight 100 lb.,	cost 5.00
No. 2, with double bottom,	capacity 5 cu. ft.,	weight 90 lb.,	cost 4.75

The scrapers will not excavate and carry to the spoil bank an amount equal to the capacities given above. Rarely does a scraper go out of the excavation full and the material which it does contain is loose soil, which has generally been previously ploughed. Authorities agree that at least 25 per cent. should be allowed for the shrinkage of the loose material when compacted in an embankment.

When the soil is sand, loose gravel, friable loam, or soft clay, the material can be excavated directly by the scraper. For harder and more compact soils a plow must first be used. A two-horse plow with driver will loosen about 400 cu. yd. of average soil per 10-hour day. If the material is a tough earth crust, a dense gumbo or hard clay, the daily output with a four-horse team and three men will be from 150 to 200 cu. yd. The following table gives the cost of plowing per 10-hour working day, under average conditions.

Labor:

Team, plow, and driver,	$3.50	
Plow holder,	1.50	
Total labor cost,		$5.00
Repairs, depreciation, etc.,		1.00
Total cost,		$6.00
Total amount of material loosened,		400 cu. yd.

Cost of loosening material; $6.00 ÷ 400 = 1½ cents per cubic yard.

For the excavation of hard soil, the cost of plowing per 10-hour day, would be as follows:

Labor:

Team, plow, and driver,	$3.50	
Plow holder,	1.50	
Beam rider,	1.50	
Total labor cost,		$6.50
Repairs, depreciation, etc.,		1.50
Total cost,		$8.00
Total amount of material loosened,		200 cu. yd.

Cost of loosening material; $8.00 ÷ 200 = 4 cents per cubic yard.

The reader is referred to the excellent discussion of the cost of moving earth with the drag-scoop scraper, in Professor Ira O. Baker's "Roads and Pavements," pages 114 to 116.

The author offers the following rule, which he has found to work well in practice.

For 50-ft. hauls or less the cost of moving 1 cu. yd. of earth will be 10 cents. For each additional 50 ft. of haul add 2 cents. When the soil is hard, add 3 cents to the figures derived from the above rule, which applies only to average soils.

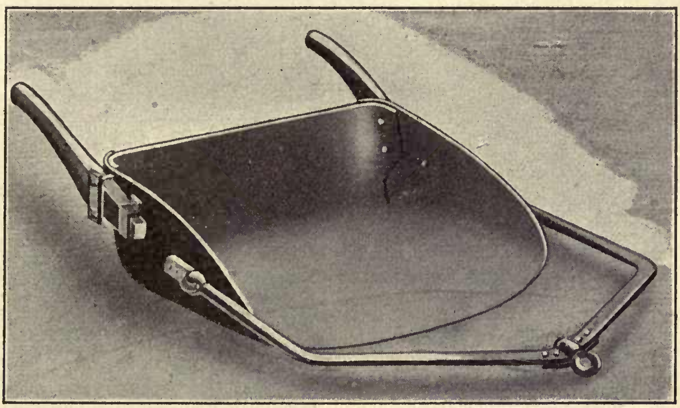
Drag scrapers are very efficient up to hauls of 100 ft. and can be satisfactorily used to 200-ft. hauls. A two-horse team and scraper can move, in a 10-hour working day, the following average amounts of loose material:

For a haul of 25 ft.,	70 cu. yd.
For a haul of 50 ft.,	60 cu. yd.
For a haul of 100 ft.,	50 cu. yd.
For a haul of 150 ft.,	40 cu. yd.
For a haul of 200 ft.,	35 cu. yd.

Drag scrapers should be worked in groups of from 4 to 10, depending upon the size of the job.

Figures 1, 2, and 3 show the front view and the rear views of a well-known make of drag scraper.

1a. Use in South Dakota.—These simple drag scrapers were used by farmers in the construction of a long road ditch in Clay County, South Dakota. The ditch had a bottom width varying from 3 to 6 ft. and a depth varying from 30 in. to 4 ft. The side slopes were $\frac{1}{2}$ to 1 on the outside and about $1\frac{1}{2}$ to 1 on the inside of the road. The work was voluntarily and coöperatively done, and each farmer furnished his team and worked a scraper. The average excavation was about 40 cu. yd. per scraper per day. The work was done under the supervision of the writer and a fairly true and uniform ditch was excavated.

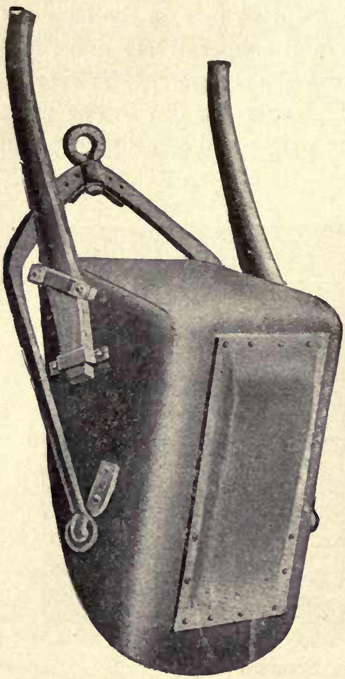


Front View of Drag Scraper.
Figure 1.

1b. Use in Minnesota.—On the experimental farm of the University of Minnesota at Crookston, Minn., some open ditches, having a bottom width of 3 ft. and side slopes of 1 on $1\frac{1}{2}$, were constructed with drag scrapers. The contractor's men averaged 41 to $43\frac{1}{2}$ cu. yd. per scraper per day, while the sub-contractors, using two teams and three men, averaged 50 cu. yd. per team per day. One man with his team averaged 60 cu. yd. per day for six days and 65 cu. yd. per day for 10 days. On this work much difficulty was experienced in excavating in soft, wet soil, as the adhesiveness of the sticky loam and clay impeded the scrapers. In general, it will be found that drag scrapers can only be used economically in fairly

dry soil and where the ditches are broad, shallow, and with slight side slopes.

2. Fresno Scrapers.—The Fresno or Buck scraper, on account of its long straight cutting edge and narrow width is especially useful and efficient in the construction of shallow ditches. It will remove a thin layer of earth and spread it out over a wide area on a road grade or spoil bank. This style of drag scraper has proved of great value in the construction of irrigation ditches and could



Rear View of Drag Scraper with Double Bottom.
Figure 2.

Rear View of Drag Scraper with Runners.
Figure 3.

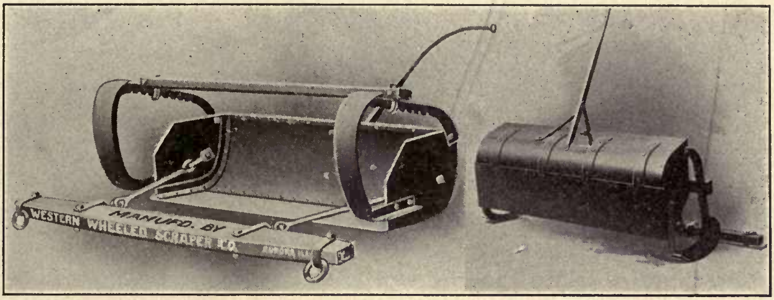
be equally serviceable in the excavation of drainage ditches under favorable conditions. The accompanying figures illustrate the Fresno scraper and the following table gives the various sizes, capacities, weights, and costs of a typical make:

No. 1, 5-ft. cutting edge, capacity 18 cu. ft., approximate weight 316 lb.	$27.00
No. 2, 4-ft. cutting edge, capacity 14 cu. ft., approximate weight 260 lb.	25.50
No. 3, $3\frac{1}{2}$-ft. cutting edge, capacity 12 cu. ft., approximate weight 245 lb.	22.50

The Fresno scraper is usually operated on large work in groups of 2 to 10, with a driver for each scraper and a laborer to load for the group. In light ditch work, the scrapers run independently and each driver loads his own scraper.

The economical haul of a Fresno is generally limited to 300 ft. It requires less time to load and unload this type of scraper than it does a two-horse wheeler, but the expense of the two extra horses on a four-horse Fresno balances these items when the haul exceeds 300 ft.

For side-hill work the Fresno scraper is especially advantageous as it will often push ahead of itself a large amount of loose material.



Buck Scraper ready to Load.
Figure 4.

Buck Scraper, Dumped.
Figure 5.

2a. Use in Colorado.—In the excavation of a ditch in eastern Colorado, having a 6-ft. bottom width, average depth of 7 ft., and side slopes of $1\frac{1}{2}$ to 1, a No. 1 drag scraper or "slip" moved by a team excavated from 30 to 75 yd., or an average of 50 cu. yd. of earth (sandy loam), in a working day of 10 hours. A No. 1 "Fresno" scraper, moved by four horses under the same conditions and on the same work, excavated from 50 to 175 cu. yd. or an average of 110 cu. yd. in the same time. The excavation cost 10 cents per cubic yard. This example shows the superiority and greater capacity of the Fresno scraper in this class of earthwork.

2b. Use in California.—During 1884 levees were constructed along the Feather and Sacramento Rivers, Sutter County, California, by the use of drag and buck scrapers.

"The levees were about 12 ft. high, 6 ft. wide on top, 90 ft. wide at base with front slope of 1 in 3, and rear slope of 1 in 4. Material was borrowed from both sides for a distance of 100 ft. from the toe of the slope; and buck

scrapers drawn by four horses were used to move the earth which was not rolled. A buck scraper 'drifted' or pushed to place up a 1 to 4 slope, about 90 cu. yd. per day."[1]

The material moved was a sandy loam with adobe in places. The "lead" was about 70 ft. and buck scrapers moved the first 70,000 cu. yd. at the rate of 55 cu. yd. per day, per scraper. The next 294,000 cu. yd. was moved at the rate of 90½ cu. yd. per scraper per day. The cost of earthwork, during the first month, when the levee embankments were low was about 10 cents per cubic yard, while the second month, when the embankments were higher, the cost of earthwork rose to 12 cents per cubic yard.

2c. Use in Nevada.[2]—The Reclamation Service used the Fresno scraper in the construction of an irrigation canal near Fallon, Nevada, during April, May and June, 1906. The soil excavated was principally a compact sand, with some gravel, loam and sub-soil of hard clay in places. The ditch had an average bottom width of 20 ft. and side slopes of 2 to 1. The spoil bank was made 6 to 12 ft. wide on top and with an average height above grade of 7½ ft. The canal was generally located along a comparatively even side hill, although in places material from cuts as deep as 20 ft., was wasted beyond a 50-ft. berm or hauled 200 to 300 ft. to reinforce the banks along adjacent depressions.

The berms were first plowed and the entire right-of-way cleared of brush before the excavation of the canal was begun. It was excavated truly to grade and the side slopes carefully trimmed. The length of the working day was eight hours. Following is a table giving the labor costs on this work.

A very good illustration of the efficiency of Fresno scrapers in the excavation of ditches is given in the following example.

The ditch was for irrigation, having an average depth of 6 to 7½ ft. and side slopes 2 to 1. The excavated material generally formed the banks. The soil excavated was a sandy loam.

The working force was made up of 10 to 12 Fresno scrapers and a two-horse plow which loosened up the earth for the scrapers. Each scraper worked continuously back and forth, down one bank and up the other. Each driver loaded and dumped his own scraper. One finishing scraper was used to trim up the sides and bottom of the

[1] Compiled from an account in "Earthwork and Its Cost," by H. P. Gillette.
[2] Abstracted from Engineering-Contracting, Nov. 3, 1909.

TABLE I

LABOR COST OF FRESNO SCRAPER WORK

Item	Rate	April		May		June		Total	
		No.	Amount	No.	Amount	No.	Amount	No.	Amount
Foremen	....	....	....	31	$97.50	1	$3.50	32	$101.00
Sub-foremen	....	1	$3.00	1	3.00	....	....	2	6.00
Four-horse Fresno drivers	$2.25	13	29.25	280¼	630.56	14½	32.62	307¾	692.42
Scraper holders	2.25	4	9.00	94¼	212.06	9	20.25	107¼	241.31
Six-horse plow drivers	2.75	....	....	22¾	62.55	....	....	22¾	62.55
Plow holders	2.75	....	....	23¾	65.30	1	2.75	24¾	68.05
Laborers, cleaning and finishing	2.25	....	....	7.5	16.87	....	....	7.5	16.87
Horses, hired	0.333	52	17.33	1,278.5	426.17	64	21.33	1,394.5	464.83
Grand total	....	....	....	....	....	....	....	....	$1,653.03
Cubic yards excavated	....	....	1,000	....	25,629	....	1,000	....	27,629
Cubic yards excavated per scraper	....	....	77	....	91.4	....	69	....	89.75

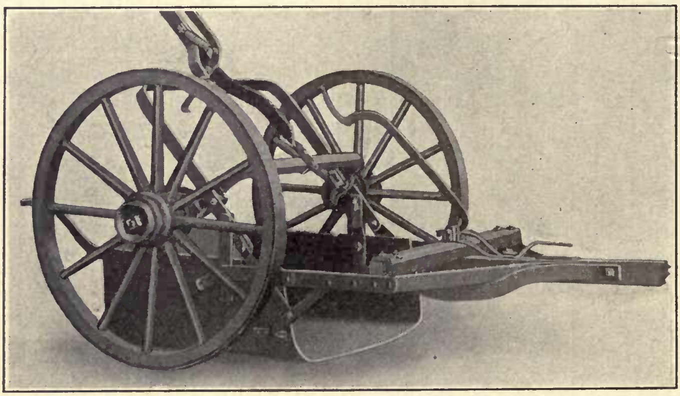
ditch. The men were paid $2.25 for an eight-hour working day. The following table gives the working cost per scraper per day.

Labor:

Four horses, Fresno and driver,	$5.30
One-tenth of two-horse plow and driver @ $3.95,	0.395
One-tenth of loader,	0.225
One-tenth of foreman @ $4,	0.40
Total,	$6.32
Average excavation per scraper per day,	125 cu. yd.
Cost of excavation per cubic yard; $6.32 ÷ 125 =	5.06 cents.

3. **Wheel Scrapers.**—The wheel scraper consists of a steel box mounted on a single pair of wheels and supplied with levers so that the box may be raised, lowered and dumped, all with the team and scraper in motion. An automatic end gate is sometimes attached to the front of the pan, and is especially useful in carrying a load down a steep grade.

Figures 6 and 7 show two positions of the scraper and the following table gives the various sizes, capacities, weights and costs of a well-known make:



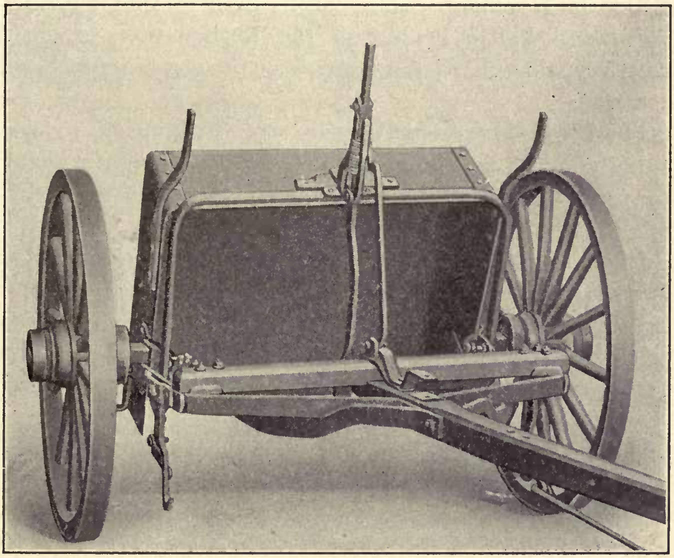
Wheel Scraper, ready to Load.
Figure 6.

No. 1, capacity 10 cu. ft., weight 450 lb.,	$45.00
No. 2, capacity 13 cu. ft., weight 690 lb.,	52.50
No. 2½, capacity 15 cu. ft., weight 700 lb., made to order.	
No. 3, capacity 17 cu. ft., weight 850 lb.,	60.00

The wheel scraper is an excellent earth mover up to a haul of

about 800 ft. It is more efficient than the drag scraper for hauls over 200 ft. The No. 3 wheeler requires the use of a snatch team in ordinary material and a No. 2 in hard material, and for long hauls this size of scraper is the most economical. For average soil and hauls not greater than 400 ft., the No. 2 wheeler is the most efficient. The average load (place measure) carried by the wheelers is as follows: No. 1, $\frac{1}{5}$ cu. yd.; No. 2, $\frac{1}{4}$ cu. yd.; and No. 3, $\frac{1}{3}$ cu. yd.

As in the case of the drag scrapers, the wheeler never leaves the excavation filled to its rated capacity. For long hauls and where the material is tough and hard to handle, it is economical to use



Wheel Scraper, Returning to Pit.
Figure 7.

shovelers to heap up the bowls of the scrapers, before the teams start.

For an excellent discussion of the cost of moving earth with wheel scrapers, the reader is referred to Prof. Ira O. Baker's book entitled "Roads and Pavements," pages 117 to 120.

The author offers the following rule, which he has made up as a result of his experience and observation.

For 100-ft. hauls or less the cost of moving 1 cu. yd. of earth will be 10 cents. For each additional 100 ft. of haul add 2 cents. When

the soil is hard add 3 cents to the figures given by the above rule, which applies only to average soils.

A two-horse team and scraper can move, in a 10-hour working day, the following average amounts of loose material:

For a haul of 100 ft.,	60 cu. yd.
For a haul of 200 ft.,	50 cu. yd.
For a haul of 300 ft.,	40 cu. yd.
For a haul of 400 ft.,	30 cu. yd.

The wheel scrapers should work in gangs of from four to six for hauls up to 400 ft. and in gangs of from eight to twelve for longer hauls.

3a. Use in Wyoming.[1]—The construction of the Whalen Dike, on the North Platte Project of the Reclamation Service, near Whalen, Wyoming, is a good example of the use of scrapers in dike construction.

The work was done from October, 1908, to January, 1909, under favorable climatic and labor conditions. The material excavated was a sandy loam, which was easily plowed and scraped. The material for the main dike, amounting to 22,598 cu. yd., was taken from a borrow pit above the dam with an average haul of 600 ft. Two-horse wheel scrapers and four-horse Maney scrapers were used in this work. The back-filling for the Fort Laramie headworks, amounting to 4,550 cu. yd., was taken from a borrow pit below the dam at an average haul of 1,000 ft. Two-wheel scrapers were used in this work.

The labor schedule for this work is as follows:

Foreman,	$4.00 per day.
Teamsters,	0.22½ per hour.
Loaders and dumpers,	0.25 per hour.
Teams,	2.00 per day.

Labor:

Distribution,	Unit cost Dike 22,598 cu. yd.	Unit cost Backfilling 4,550 cu. yd.
Foreman,	$0.014	$0.030
General work,	0.014	0.017
Hauling,	0.124	0.181
Plowing,	0.017	0.044
Snap team and driver,	0.027	0.036
Loading and placing,	0.029	0.057
Total labor,	$0.225	$0.365
Supplies,	0.002	0.007
Blacksmithing,	0.001	0.010
Total unit cost,	$0.228	$0.382

[1] Abstracted from Reclamation Record, March, 1909.

3b. Use on Chicago Drainage Canal.—The following data give the cost of excavation work on the Chicago Drainage Canal, referring to those sections where wheeled scrapers were used.

"The soil moved by wheelers was a 'fairly soft clayey loam' and the average haul was about 400 ft., the material being deposited in spoil banks.

"On the Brighton Division, Section K, 68,300 cu. yd. were moved in 62 days, the average force being 23.8 men and 36.8 teams with drivers. There were two plows and 24 No. 3 wheelers in use, hence each plow loosened 550 cu. yd., and each wheeler moved 46.1 cu. yd. per 10-hour day, while the average output, including snatch teams of which there appear to have been one for every three wheelers, and including plow teams, was about 30 cu. yd. per day per team.

"For Summit Division, Section E, the haul was 400 ft. The number of men engaged is not given, but we have assumed two-thirds man per team, which is not far from right."

TABLE II

AMOUNTS AND COST OF WHEEL SCRAPER WORK

Stations	Average		Total excavation, cubic yards	Daily average, cubic yards		Ratio of teams		Cost, cents per cubic yard	(1)
	Fill ft.	Cut ft.		Per team	Per Whlr.	Wheelers to plows	Wheelers to team		
460–470	12	8.0	94,879	29.8	42.2	$5\frac{1}{3}$–1	$4\frac{4}{10}$–1	15.1	(2)
470–480	12	8.3	98,515	27.1	39.3	$4\frac{9}{10}$–1	$4\frac{4}{10}$–1	16.6	(2)
480–490	11	7.0	85,761	24.4	35.2	$4\frac{8}{10}$–1	$4\frac{3}{10}$–1	18.4	(2)
490–500	7	3.4	33,185	35.0	50.1	$4\frac{9}{10}$–1	$4\frac{4}{10}$–1	12.9	(3)
500–507	7	4.3	29,678	28.3	42.1	$4\frac{8}{10}$–1	$3\frac{7}{10}$–1	15.9	(4)

(1) Assuming two-thirds man per team.
Material: (2) Very stiff blue and yellow clay with a few large boulders.
(3) Loamy clay.
(4) Stiff clay.

"The table shows that there were about five wheelers to each plow, hence each plow team must have loosened about 200 cu. yd. in 10 hours, the hardest section being from Sta. 480 to Sta. 490, where 168 cu. yd, were the average per plow team per day. Doubtless two teams were worked on each plow. One snatch team to every 4.4 wheelers appears to have been the average, or each snatch team loaded about 175 cu. yd. a day at a cost of 2 cents per cubic yard."[1]

[1] From "Earthwork and Its Cost," by H. P. Gillette.

3c. Use in Pennsylvania.[1]—About 8,000 cu. yd. of earth were moved with wheel scrapers, near Homewood, Pa., in the construction of a siding for the Pennsylvania Railroad. No. 3 Western wheel scrapers were used, and the earth was entirely excavated from borrow pits, with hauls ranging from 150 ft. to 450 ft. with an average haul of 350 ft. The following is the labor schedule based on a 10-hour working day:

1 three-horse snap team,	$3.50
1 three-horse plow team,	7.50
1 foreman,	3.00
2 scraper loaders, @ $1.75,	3.50
1 dumpman,	1.75
1 two-horse scraper team,	5.00

The table below gives the cost of this work for a period of eight days.

TABLE III

COST OF WHEEL SCRAPER WORK

Date	Weather	Number of scraper loads	Total cubic yards	Average load cu. yd.	Total cost	Cost per cu. yd
1906						
Sept. 11..	Fair............	352	141	0.401	$38.07	$0.270
Sept. 21..	Wet and muddy.	352	141	0.401	38.07	0.270
Sept. 22..	Wet and muddy.	576	230	0.399	60.70	0.263
Sept. 24..	Fair............	572	229	0.401	50.84	0.222
Sept. 25..	Fair............	528	211	0.399	59.74	0.283
Sept. 26..	Fair............	580	232	0.400	56.04	0.241
Sept. 27..	Fair............	473	189	0.399	44.07	0.233
Sept. 28..	Fair............	473	189	0.399	57.18	0.302
	Totals	3,906	1,562	....	$404.71	....
	Averages......	....	....	0.39975	....	$0.265[2]

3d. Use on Railroad Work.—One of the editors of Engineering-Contracting in the issues of September 4 and 25, 1907, gives very instructive accounts of the use of the wheel scraper in the construc-

[1] Abstracted from Engineering-Contracting, July 17, 1907.

[2] This is the average of the eight items of the last column. The average obtained by dividing $404.71 by 1562 is $0.258. The figures for "Total Cubic Yards" in the fourth column were obtained by multiplying the "Number of Scraper Load" in each case by 4 cu. yd. This is assuming that the No. 3 scraper contains an average load (place measure) of 0.4 cu. yd.

tion of railroad grades. The following abstract is made to show the reader the increase of cost of excavation with the length of lead and one case where with long lead the cost was lower than for shorter leads in the other cases.

The labor schedule for all of the work based on a 10-hour working day, was as follows:

Foreman,	$3.00
Extra foreman,	2.50
Scraper team and driver,	4.75
Four-horse plow team and two men,	9.20
Three-horse snatch team and one man,	6.00
Three-horse plow team and two men,	7.50
Two-horse snatch team and one man,	4.60
Loaders,	1.60
Laborers,	1.50
Water boy,	1.00

A four-horse plow team was used to loosen the earth and in Case V, a three-horse team was used when sand was encountered. A three-horse snatch team was used in loading the scrapers and in Case V, a two-horse team was used in sandy soil. The wheel scrapers were all No. 2½ with a capacity of about ⅓ cu. yd., place measurement. Two men loaded and dumped each scraper, except in Case I. The work was done in the fall of the year when climatic conditions were favorable for grading work.

Case I.—The material moved in this case was a sandy loam, which was easily plowed and scraped up. The lead was 260 ft., making a round trip of 600 ft. for each team and a total distance per day for each scraper of about 12 miles. Five scrapers were worked together on this job. The average amount of earth moved per 10-hour day was 34 cu. yd. for each scraper and 31 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman,	$0.017
Scrapers,	0.138
Plowing,	0.052
Snatching,	0.034
Loaders,	0.018
Dumping,	0.008
Water boy,	0.006
Total cost per cubic yard,	$0.273

Case II.—The material excavated on this work was an average clay, fairly easy to handle. The lead was 300 ft., a round trip of 700 ft. for each team and a total distance per day for each scraper of about 12 miles were made. Five scrapers were used together. The average amount of earth moved during a 10-hour day was 30 cu. yd. for each scraper and 19 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman,	$0.019
Scrapers,	0.158
Plowing,	0.057
Snatching,	0.037
Loaders,	0.020
Dumping,	0.016
Water boy,	0.004
Total cost per cubic yard,	$0.311

Case III.—The material on this work was a wet clay, saturated with water from recent rains and local springs. The lead was 400 ft., making a round trip of 1,000 ft. for each team and a total distance traveled per day of 12½ miles. Five scrapers were used in a gang as in the previous cases. The embankment was made on marshy land and the services of an extra laborer were required to shovel earth ahead of the teams. The average amount of earth moved was 22 cu. yd. for each scraper and 13 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman,	$0.026
Scrapers,	0.216
Plowing,	0.080
Snatching,	0.052
Loaders,	0.028
Dumping,	0.039
Water boy,	0.009
Total cost per cubic yard,	$0.450

Case IV.—The material excavated on this work was a fine sand which retarded the work by allowing the wheels of the scrapers to sink below the surface until the bottoms of the bowls touched. The lead was 500 ft., making a round trip of 1,000 ft. for each team and a total distance traveled per day of 12½ miles. Six scrapers were worked in a gang. The average amount of earth moved was 21½ cu. yd. for each scraper and 13 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman,	$0.024
Scrapers,	0.222
Plowing,	0.073
Snatching,	0.050
Loaders,	0.026
Dumping,	0.027
Water boy,	0.008
Total cost per cubic yard,	$0.430

Case V.—The material was a light red clay and sandy loam running into sand in the bottom of the cut. The cut required the excavation of 2,000 cu. yd. The lead was 700 ft. and the total distance traveled per day by each team was 6 miles. The embankment was made over a tide-water marsh, and in many places the surface would not support a man. There brush was placed to form a matting. Four men were employed to shovel earth ahead of the wheelers.

On one side of the cut was a bluff about 15 ft. high, where the scrapers could not be used. A gang of extra laborers with a foreman pulled this bank down with pick and shovel and it was removed by the scrapers. The average amount of earth moved was 23 cu. yd. for each scraper and 15½ cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is as follows:

Foreman,	$0.02
Scrapers,	0.21
Plowing,	0.053
Snatching,	0.03
Loaders,	0.02
Dumping,	0.033
Water boy,	0.001
Total cost of scraper work,	$0.367
Tearing down bank:	
Foreman,	$0.006
Extra laborers,	0.066
Total,	$0.072
Total cost of excavation per cubic yard,	$0.439

The following table has been compiled from the above data to show the effect of the lead, soil conditions, etc., upon the efficiency of the work.

TABLE IV

EFFECT OF LEAD AND SOIL UPON COST

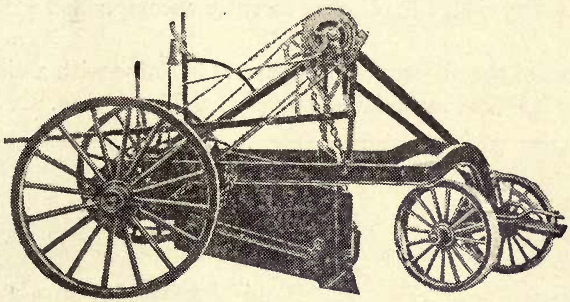
Case	Lead	Average amount moved by scraper	Average scraper cost per cubic yard	Average total cost per cubic yard	Scraper cost divided by total cost	Soil excavated
I	260 ft.	34 cu. yd.	$0.138	$0.273	50.5 per cent.	Sandy loam.
II	300 ft.	30 cu. yd.	0.158	0.311	50.8 per cent.	Clay.
III	400 ft.	22 cu. yd.	0.216	0.450	48.0 per cent.	Wet clay.
IV	500 ft.	21½ cu. yd.	0.222	0.430	51.6 per cent.	Fine sand.
V	700 ft.	23 cu. yd.	0.210	0.367	57.2 per cent.	Red clay, loam and sand.

The plow teams in the five cases loosened during each 10-hour day the following average amounts. Case I, 170 cu. yd.; Case II, 150 cu. yd.; Case III, 115 cu. yd.; Case IV, 125 cu. yd.; Case V, 164 cu. yd. It will be noted that these amounts are all about one-half of what they should have been, considering the soil and climatic conditions. The dumping cost is also high in the last four cases. One man for each scraper would have been sufficient. It is evident that under the conditions existing on this work, that far more efficient work would have been done if about 8 to 10 scrapers had been used in a gang. The same foreman, loaders and dumpers could have taken care of the larger number of scrapers.

The figures in the fifth column of the above table do not include the expense of superintendence, inspection, repairs, depreciation, etc. Note that the cost of the scraper work was about 50 per cent. of the total cost.

4. Maney Four-wheel Scraper.—Recently a four-wheel scraper has come into use, known as the Maney Four-wheel Scraper. It is made by the Baker Mfg. of Chicago, Ill. A pan having a capacity of 1 cu. yd. is swung on chains between a frame, which is carried on two trucks. The pan is hung so that the front or cutting edge only touches the ground. The front wheels are underhung, so that short and sharp turns may be made. The pan is operated by four levers, which are all within easy reach of the driver and operator, who is seated just behind the rear truck and on the right side of the machine.

The motive power may be horses or a traction engine. The latter is generally used in the place of a snatch team to assist the regular team in filling the scraper. The pan when filled is elevated automatically by a sprocket chain. The whole machine then is moved to the dump where the pan is elevated to the proper height, when an automatic trip throws the clutch on the axle out of gear, stopping the winding and preventing the machine from becoming spool bound. The load is then dumped through a gate in the rear of the pan. Fig. 8 shows a general view of this scraper. The cost of this scraper is $260 f.o.b. factory.



The Maney Four-wheel Scraper.
Figure 8.

4a. Use in Oregon.—The Maney four-wheel scraper was used in the construction of the South Branch Canal on the Klamath Project near Klamath Falls, Oregon. This canal is unique in its being built in an elevated embankment above the general level of the original surface of the land. The top of the dyke is 14 ft. and the bottom of the finished canal is 8 ft. above the original ground surface. The material was placed in 6-in. layers, sprinkled, and rolled only by the tractive action of the wheels of the scrapers. The average haul from borrow pit to dyke was 400 ft. The material excavated from the borrow pit was sandy loam for the first 18 in. and underlying this 3½ ft. of hard pan. This latter material required 8 to 10 head to move the plow through it. The total amount of material handled was 170,000 cu. yd. and the average cost of handling per cubic yard was 14 cents.

4b. Use in Colorado.—The use of this four-wheel scraper for three years in the construction of reservoir dykes and irrigation ditches in Colorado, where a friction drum and cable attached to a traction engine were used for extra power in loading, gave good results. Two sizes of this machine were used, a three-horse holding

1 yd. and a four-horse holding 1½ yd. The material averaged from a loose sand to a very stiff clay. A loading average was made of 100 loads per hour with each loading-engine. The cost of excavating and moving the dirt was from 5 to 8 cents per cubic yard on short hauls of 100 to 200 ft.; for longer hauls the cost was 1 cent per cubic yard per 100-ft. increase of length of haul. The larger size of scraper can be economically used up to a 2,000-ft. haul.

Figure 9 shows a gang of scrapers using a traction engine in the place of snatch teams.

4c. Use in Illinois.[1]—The excavation of a site for a large artificial lake at Libertyville, Illinois, was recently accomplished with Maney scrapers.

The area of the pit excavated was oval in shape with a diameter of about 400 ft. The material was a very hard brick clay.

A Series of Maney Scrapers with Traction Engine Auxiliary for Loading. Figure 9.

The scrapers were loaded, at first, with snatch teams but later a 10-h.p. double-drum engine was used. The engine was placed on the bank of the pit and a ½-in. diameter steel cable run from each drum through a two-sheave steel pulley block anchored to a "deadman" about 50 ft. away. The outer end of each cable was fastened to a hook, attached to the tongue of a scraper. The operation of each drum of the engine wound up the cable and pulled the scraper through the plowed ground toward the bank of the pit. Either one or two scrapers could be loaded at one time. Generally one scraper proceeded to the dump, while the other one drew the cables back to

[1] Abstracted from Engineering-Contracting, September 18, 1912.

the loading point. The average haul was about 500 ft., varying from 200 to 1,200 ft.

Each scraper required the services of only one man who rode, drove the team and operated the levers for loading and dumping the scoop. The operation of the engine was controlled by one man.

The following table gives a statement of the work for July, 1912.

TABLE V

LABOR AND OUTPUT ON FOUR-WHEEL SCRAPER WORK

Date	Working hours			Number of loads
	Foreman	Laborers	Man and team	
July 1, 1912	10	40	90	310
July 2, 1912	10	40	90	313
July 5 and 6, 1912	20	70	170	628
July 9, 1912	10	40	80	257
July 10, 1912	10	40	80	281
July 11, 1912	10	40	80	316
July 12, 1912	10	40	80	277
July 15, 1912	10	40	90	269
July 16, 1912	10	30	90	362
July 17, 1912	10	40	90	328
July 18, 1912	10	40	90	324
July 19, 1912	10	40	90	445
July 23, 1912	10	28	72	312
July 24, 1912	10	30	90	324
July 26, 1912	10	30	80	328
July 27, 1912	10	40	90	322
July 29, 1912	10	40	80	320
July 30, 1912	10	40	82	276
July 31, 1912	10	40	80	346
Total	200	748	1,694	6,338

From the above table the following data may be compiled:

6,338 loads of about 29 cu. ft. equal 5,106 cu. yd. (place meas.)
Average number of cu. yd. excavated per team-hour, 3.01
Average number of cu. yd. excavated per scraper-hour, 3.92
Average number of cu. yd. excavated per scraper per day, 35.3
Average number of cu. yd. excavated yer day, 255.3

The labor cost for this work is given as follows:

1 foreman,	$3.00
1 dumpman,	2.25
2 pitmen, @ $2.25,	4.50
1 engineer,	2.75
9 teams and men with 7 scrapers @ $.500	45.00
Total labor cost per day,	$57.50
Average excavation per day,	255.3 cu. yd.

Labor cost of excavation, $57.50÷255.3=$0.225 per cubic yard.

5. Résumé.—The field of usefulness of the scraper is large and varied. In the construction of embankments, levees in drainage work, and fills in railroad work, the scraper is a time-honored and efficient tool. For the excavation of broad, shallow ditches for drainage and irrigation systems, the scraper has been used to a more limited extent. It is a familiar tool in the grading of streets, the digging of cellars for buildings and the excavation of large shallow areas for reservoirs and the foundations for various structures. The scraper is an efficient and economical excavator where the yardage is small, roughly speaking, less than 50,000 cu. yd. and within the scope of the type employed. Considering the first part of the above statement, a dry-land excavator can generally be used for the construction of levees, when the job is greater than 50,000 cu. yd., at a cost of about 50 per cent. less than with a scraper. In the same way a steam shovel supersedes the scraper in the excavation of large foundations, street and railroad cuts, etc. In the excavation of small ditches, the wheel excavator is a much more efficient machine and for large ditches, the dredge entirely supplants the scraper.

The Fresno scraper has been used with considerable success in the southwest on ditch and embankment construction. This is especially true of side-hill work, when the ditch lies partly in cut and partly in fill. The scraper works downhill, pushing a large amount of earth ahead of itself into the embankment, which is consolidated by the tramping of the teams. For ditches from 6 to 20 ft. wide on the bottom, side slopes of $1\frac{1}{2}$ to 1, and less, and for depths from 3 ft. to 6 ft., the Fresno scraper will, under fair working conditions, average about 500 cu. yd. per working day of 10 hours and at an operating cost of about 8 cents per cubic yard.

The drag scraper can operate successfully and economically up to a haul of 200 ft. and the wheel scraper up to a haul of 800 ft.

The cost of excavation is rather difficult to formulate and one

upon which authorities differ.[1] The following table is based upon the rules given on pages 3 and 13 and will be found to be approximately correct, under average working conditions.

TABLE VI

COST PER CUBIC YARD OF SCRAPER WORK

I. Drag Scraper

Character of soil	Length of haul			
	50 ft.	100 ft.	150 ft.	200 ft.
Average soil	$0.10	$0.12	$0.14	$0.16
Hard soil	$0.13	$0.15	$0.17	$0.19

II. Wheel Scraper

Character of soil	Length of haul							
	100 ft.	200 ft.	300 ft.	400 ft.	500 ft.	600 ft.	700 ft.	800 ft.
Average soil	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20	$0.22	$0.24
Hard soil	$0.13	$0.15	$0.17	$0.19	$0.21	$0.23	$0.25	$0.27

The figures of cost given in the above table include plowing, loading, hauling, dumping, spreading, supervision, and repairs.

6. Bibliography.—For additional information, see the following:

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2. Earthwork and Its Cost, by H. P. Gillette, Second Edition, published in 1912 by McGraw-Hill Book Co., New York. 54 figures, 5½ by 7 in., cost $2.

3. Economics of Road Construction, by H. P. Gillette, published in 1906 by Engineering News Publishing Co., New York. 41 pages, 9 figures.

4. Handbook of Cost Data, by H. P. Gillette, published in 1910 by Myron C. Clark Publishing Co., Chicago. 1,900 pages, 4¾ by 7 in., cost $5.

5. Roads and Pavements, by Ira O. Baker, published in 1903 by John Wiley & Sons, New York. 655 pages, 171 figures, 6 by 9 in., cost $5.

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[1] See Baker's "Roads and Pavements" and Gillette's "Earthwork and Its Cost."

2. A Cable-power Scraper for Earth Excavation, C. G. Newton; Engineering News, October 20, 1904. Illustrated, 500 words.

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11. Scraper Excavators; Engineering News, March 21, 1907.

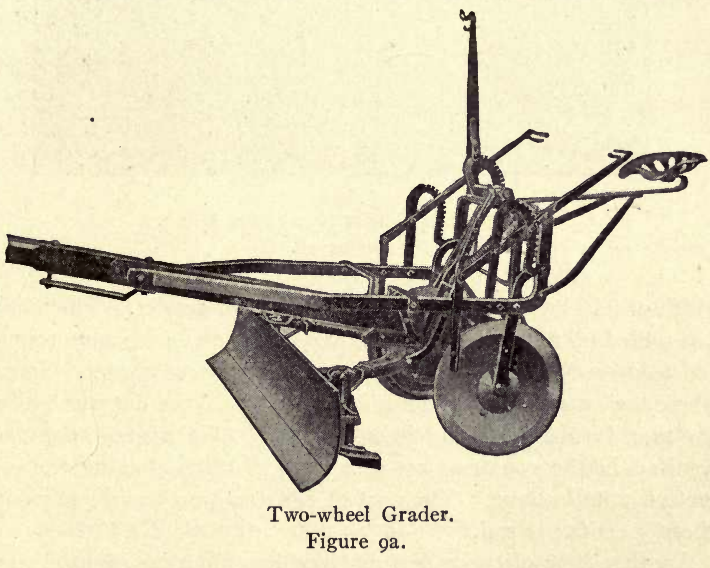
CHAPTER II

ROAD OR SCRAPING GRADERS

8. General Description.—The scraper grader, or road machine as it is often called, consists of a scraper blade suspended from a frame mounted on either two or four wheels. The blade is so hung from the frame that it may be placed at any angle, horizontally or vertically. The grader is usually hauled by four or six horses, although for shallow road ditch work, especially through hard soil, a traction engine is often used and furnishes a steadier power.

The scraping grader is operated by making successive shallow cuts and gradually working the excavated material from a lower to a higher elevation.

9. Two-wheel Grader.—The simplest form of scraping grader is the two-wheel grader. The blade can be raised or lowered and



Two-wheel Grader.
Figure 9a.

adjusted vertically or horizontally. The machine is hauled by two or four horses and is operated by one man who sits at the rear of the machine. Fig. 9a shows one type of grader, with a pivoted blade, which can be set in any horizontal position by the curved arm

fastened to the rear of the blade. Two levers adjust the blade in a vertical position. The wheels are flanged to prevent lateral slipping of the machine on an inclined surface. This machine weighs 600 lb. and costs $125. It will cut V-shaped ditches, as shown in Fig. 10, up to a depth of 24 in. and at an average cost of 3 cents per rod.

9a. Use in Mississippi.—The machine shown in Fig. 10 is the Twentieth Century Grader made by the Baker Mfg. Co. of Chicago, Ill. It has been used extensively in Mississippi, Louisiana, and Texas, in the excavation of small lateral ditches. On large plantations near Greenville and Yazoo City, Mississippi, drainage ditches, having a bottom width of 2 ft., average depth of 2 ft. and average top

Two-wheel Grader Excavating Ditch.
Figure 10.

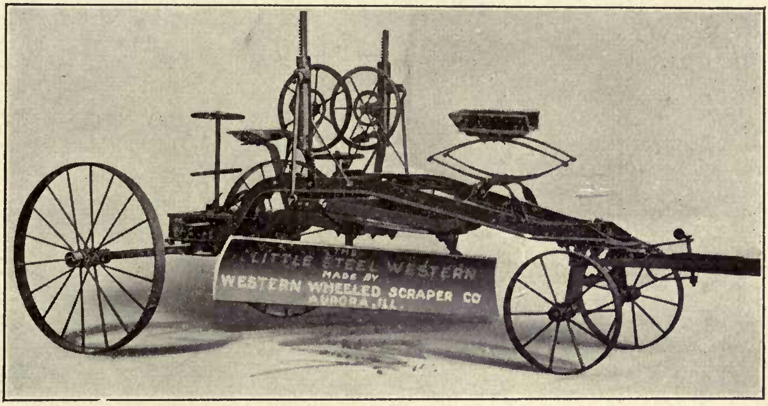
width of 6 ft. have been constructed with this grader. The machine was pulled by four mules and the services of two men were required, one to drive the mules and the other to operate the grader. In cases where the excavation was made in soft soil and the cut was uniform, one man furnished all the labor required. The average day's work resulted in the construction of $\frac{1}{2}$ mile of ditch, having the cross-section noted above. The cost of construction was $4 per day or about 3 cents per rod.

Another form of two-wheel machine has the axles pivoted so that the wheels, either one or both may be inclined to prevent the lateral motion of the machine on an inclined surface or as a result of the side thrust of the blade.

10. Four-wheel Grader.—The four-wheel grader is made in many

forms and sizes. A typical make of the small light grader is shown in Fig. 11.

10a. **Light-wheel Grader.**—The blade is turned or moved horizontally by means of a circle and adjusted vertically by the wheel-operated gear lifts. The rear axle is pivoted in the center so that the rear wheels may be inclined in either direction to counteract side draft. Also by a simple gear mechanism the frame of the machine can be shifted on the rear axle to either side. This allows one wheel to run along the side of a ditch when making a cut. The front wheels are small and can cut under the frame so that the machine

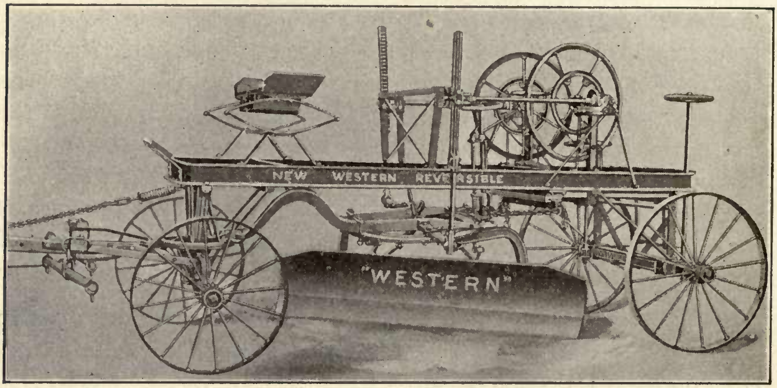


Light Four-wheel Grader.
Figure 11.

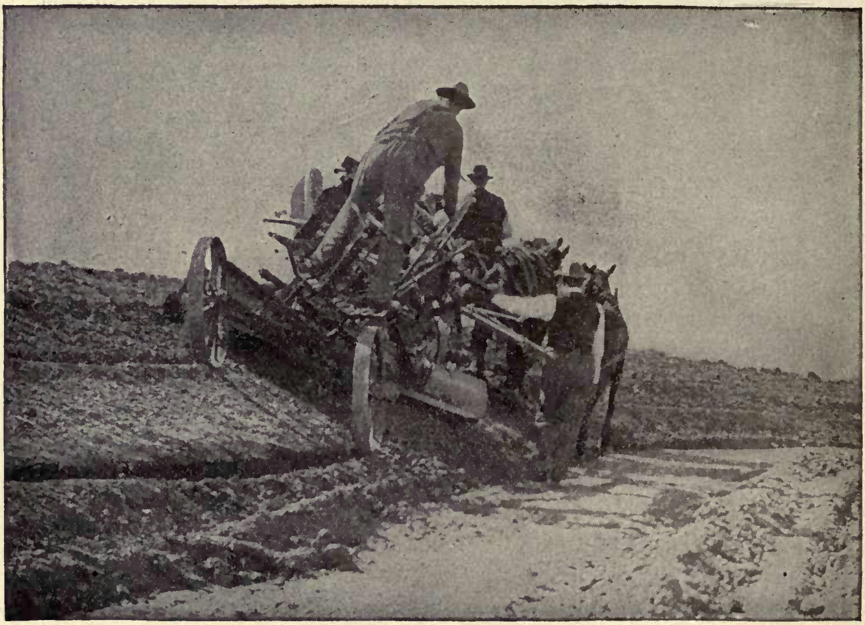
may be turned short. This machine weighs 1,400 lb., has a blade 14 in. wide and 6 ft. long and costs $135, f.o.b. factory.

10b. **Standard-wheel Grader.**—The standard size of scraping or road grader is shown in Fig. 12. This machine is constructed and operated in a similar way to the light-weight scraping grader, described above. The blade of the standard size machine is 7 ft. long and the rear axles may be extended to a total width of nearly 8 ft. The weight of the machine is 2,700 lb. and the cost is $225, f.o.b. factory.

11. **Reclamation Grader.**—A scraping grader or ditcher, which is specially designed for the construction of ditches is shown in Fig. 15. This machine has been used in the construction of a number of irrigation ditches in Colorado, Idaho and Montana. This machine has a much greater latitude in the vertical adjustment of blade and the lateral or oblique motion of the wheels of both trucks than the



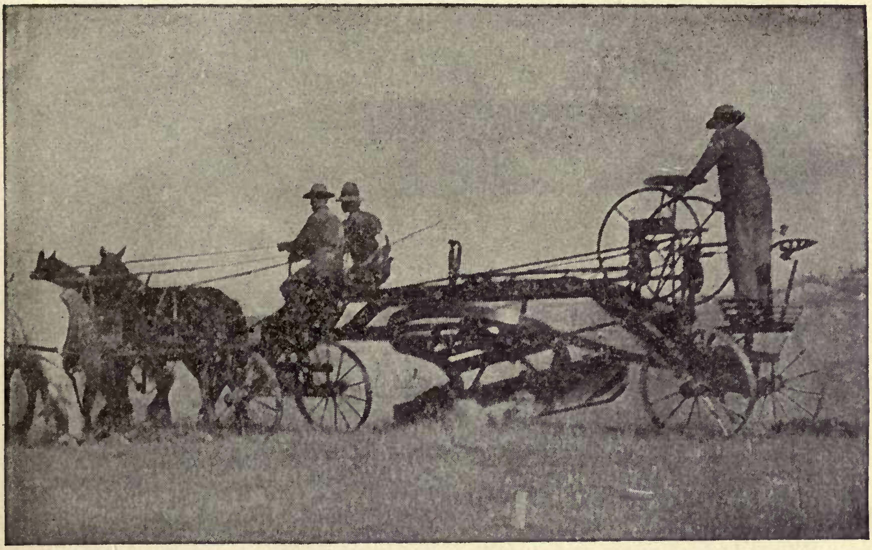
Standard Road Grader.
Figure 12.



Reclamation Grader Excavating Irrigation Ditch.
Figure 13.

ordinary scraping or road grader. It can excavate ditches to a depth of 3 ft. below the original surface, to a bottom width of 10 ft. and with side slopes as steep as 2 to 1. It is hauled with 12 horses, weighs 3,800 lb. and costs $750. The cost of construction of irrigation ditches has run from 1 cent per cubic yard to 8 cents per cubic yard, depending on the cross-section of the ditch and the character of the soil.

The author has not known of this machine ever having been used in the construction of a drainage ditch, but believes that it would be satisfactory for dry soil, which is not too hard or stiff. Figs. 13 and

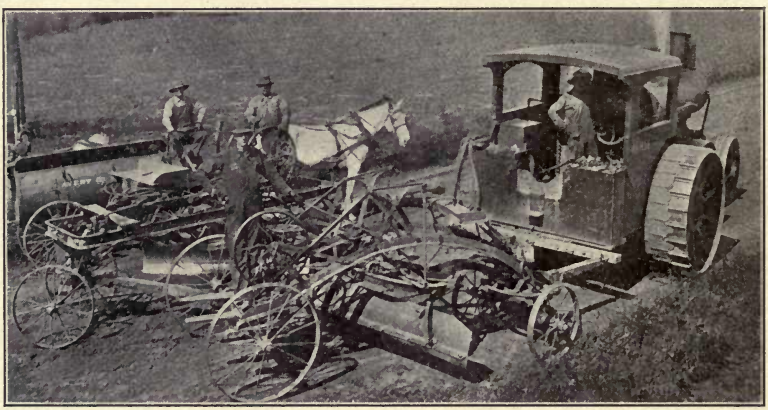


Reclamation Grader Commencing Irrigation Ditch.
Figure 14.

14 show this ditcher in operation in the construction of a large ditch at Broomfield, Colorado.

11a. Use in Iowa.—Two Reclamation graders have recently been used in the construction of roads in Van Buren County, Iowa. The graders were hauled by a 60-h.p. gasoline traction engine. The work comprised the grading up of 60 miles of road with the moving of the earth from the side ditches to the center. The road was 30 ft. wide between centers of side ditches and crowned to a height of 3 ft. above the bottoms of the side ditches. The latter had bottom

Two Reclamation Graders on Road Construction.
Figure 15.



Two Road Graders Drawn by Traction Engine.
Figure 16.

widths of 20 in. The cost of the work was $20 per mile. The graders in use are shown in Fig. 15.

12. Résumé.—The road grader can be used efficiently in the construction of roads and of small ditches. The limitations of this machine depend to a great extent upon its size and construction. The two-wheel grader is adapted to the grading up of roads and the excavation of small ditches where the soil is dry and not too hard. The four-wheel grader is economical in the grading up of roads and the excavation of the upper sections of large ditches. The type of grader shown by the Reclamation grader is especially adapted to side-hill work and the excavation of irrigation lateral ditches. A grader of any kind cannot operate successfully in very loose and wet soils nor in very hard soils.

Where a large amount of road construction is included in one contract, it is advisable to use a traction engine to haul the grader. In making the cuts and spreading the material over a roadway, considerable economy of time and labor may be effected by using the graders in pairs. A view of two road graders drawn by a traction engine is shown in Fig. 16.

The standard road grader will require the services of two men and five horses and the operating expenses will average $12 per day. In the excavation of road ditches and the grading up of roads, for ordinary clay and loam with slight grades, the grader will make an output of about 1,000 cu. yd. or cover about 18,000 sq. yd. of road surface.

CHAPTER III

ELEVATING GRADERS

13. General Description.—The elevating grader consists of a frame supported on two pairs of wheels. From the frame is suspended a plow and transverse inclined frame, which carries a wide traveling, endless belt. The moving belt frame or elevator is so constructed and supported, that the extension of the belt beyond the center of the machine may be varied and the inclination of the belt changed. The form of plow used may be either of the dise or ordinary moldboard type. The plow is suspended from an independent beam, which is so hung from the main frame that the plow may be adjusted in four ways; longitudinal, transverse, vertical, and tilting. The plow loosens the soil and raises it upon the lower end of the inclined elevator, which carries it to the outer and upper end of the elevator, where it falls on to the spoil bank or into wagons.

This machine is generally constructed in three sizes; the large, or "Giant," the standard, and the small, or "Junior."

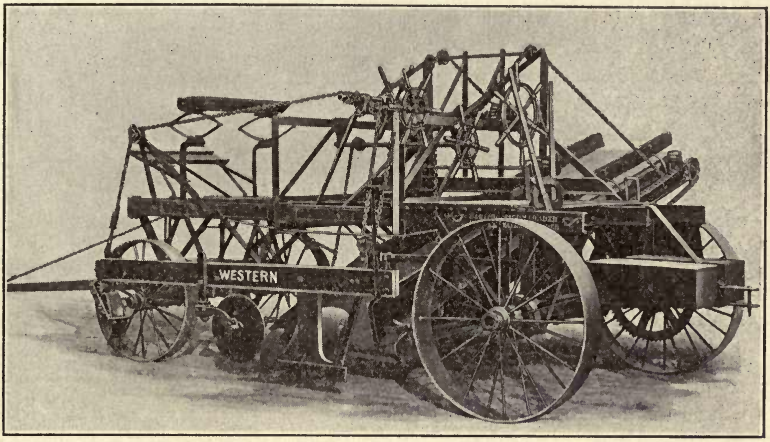
13a. Large Elevating Grader.—The large size is built to meet the requirements for a machine with a specially long elevator. It will convey earth a distance of 30 ft. from the plow, the elevator being made in sections to operate in 18-, 21-, 27- and 30-ft. lengths. It is designed to excavate a ditch having a maximum top width of 50 ft. and a maximum depth of 7 ft. Its weight is 12,000 lb. and cost is $1,400 f.o.b. factory.

13b. Standard Elevating Grader.—The standard is the popular size and generally used under average conditions. The elevator is made so as to convey earth 15, 18 and 21 ft. from the plow. Its weight is 9,400 lb. and cost is $1,000 f.o.b. factory.

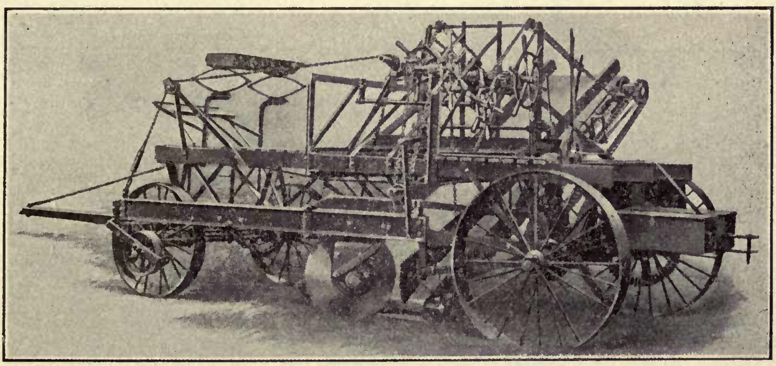
13c. Small Elevating Grader.—The small size is especially adapted for working in narrow cuts or in constructing road ditches, where the earth is moved a short distance transversely. The elevator is constructed to move material either 15 or 18 ft. from the plow. Its weight is 8,600 lb. and cost is $950 f.o.b. factory.

Figures 17, 18 and 19 show respectively, the plow side and the elevator side of a standard size elevating grader.

14. Gasoline-engine Elevator Drive.—The latest type of elevating grader uses a gasoline-engine attachment for driving the elevator. Although this innovation has not been in use long enough to thoroughly demonstrate its efficiency, the few cases where the



Plow Side of Elevating Grader.
Figure 17.

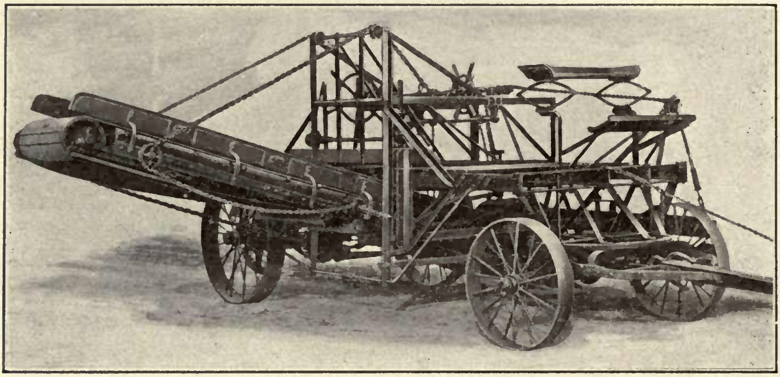


Plow Side of Elevating Grader.
Figure 18.

writer has known of its use show favorable results. The engine used is usually a four-cylinder, 25- or 30-h.p. automobile type of gasoline engine. The weight of engine attachment is about 1,000 lb. The principal advantage of the special engine drive over the ordinary traction drive is the uniform and strong movement of the carrier,

regardless of the tractive force of the wheels of the grader or the load on the carrier.

15. Animal Motive Power.—The motive power of an elevating grader is usually from 10 to 16 head of horses or mules, depend-



Elevator Side of Elevating Grader.
Figure 19.

ing on the size of the machine and the character of the soil to be excavated.

16. Traction-engine Motive Power.—Where a large amount of

Traction Engine and Elevating Grader on Road Construction.
Figure 20.

motive power is required and for a large contract, as in the construction of several miles of drainage ditches through heavy gumbo

soil, the use of a traction engine is more economical and preferable to the use of animal power. The size of traction engine required depends on the size of the grader and the character of the material to be excavated. A standard size elevating grader will, under average conditions, require about a 25 tractive horse-power engine. Fig. 20 shows a steam traction engine and elevating grader constructing a road through gumbo soil in Nebraska.

17. Use of Elevating Grader in South Dakota.—From August, 1910 to December, 1911, three lines of lateral ditches, having an average length of 6 miles each, were constructed tributary to the Clay Creek Ditch in Clay County, South Dakota. The contract required the excavation of ditches having bottom widths of 3 ft., side slopes of 1 to 1 and depths, varying from 3 to 7 ft. The contract price was 10 cents per cubic yard for excavated ditch section and the excavated material formed into a suitably graded-up road. The upper section of the ditches was entirely excavated by elevating graders drawn by traction engines. The graders used were the New Era Senior and the Standard Western. Hart-Parr gasoline engines having a capacity of 45–25 tractive horse-power were used. An average of 800 cu. yd. of rather stiff loam and clay were excavated in a 14-hour day. About 60 gal. of kerosene per day was used as fuel for each engine and the cost of labor was as follows:

1 engineer for engine, $3.50 per day and board.

1 operator for elevating grader, $3 per day and board.

17a. Reclamation Service, South Dakota.—A large earthen dam was constructed across Owl Creek near Belle Fourche, South Dakota, to form the reservoir for the Belle Fourche Project of the Reclamation Service. During the early stages of this work, elevating graders were used to excavate the material from the borrow pits, which were located on each side of the valley near the ends of the dam and the excavated material was hauled by means of $1\frac{1}{2}$ cu. yd. dump wagons. They were drawn by either two- or three-horse teams and the average load was $\frac{1}{2}$ cu. yd.

The graders were Western Elevating Graders of standard size. One grader was drawn by a 32-h.p., 20-ton, steam traction engine and the other by 12 or 14 horses.

The following report of hauling was submitted by Mr. F. C. Magruder, Project Engineer, and is given entire, as being of especial interest in this matter.

Wages paid were $1.75 per 10-hour day for teamsters and $1 per day for horses. The dirt from Anderson's pit was brought up a 5-per

cent. grade making a lift of 60 ft. C. Wilson had a lift of 45 ft. Pits 95–97, 56–96 and 332–372 were all at a higher elevation than the dam and the haul was all down grade. Part of the wagons were drawn by three horses and part by two horses. J. Lamoro used two horses and A. Lamoro used three horses; the other outfits used part two's and part three's.

TABLE VII

COST OF HAULING DIRT WITH 1½ YARD DUMP WAGONS

Pit No.	Foreman	Yardage	Cu. yd. per wagon day	Cost per wagon day	Length of haul ft.	Cost per cu. yd.	Cost per cu. yd. per 100
290–291	J. Lamoro...	7,250	76	4.39	600	$0.058	$0.0097
230–231	Anderson.....	5,070	48.3	5.34	1,200	0.111	0.0092
110–112	A. Lamoro...	20,710	78	5.20	1,300	0.074	0.0057
231	C. Wilson....	6,730	49.2	4.91	1,000	0.100	0.0100
332–372	J. Lamoro....	4,550	51.4	4.48	1,500	0.087	0.0058
110	Cotter.......	2,270	28.4	4.91	2,000	0.173	0.0086
95–97	Cotter.......	25,900	25.7	4.91	2,600	0.194	0.0075
56–96	Cotter.......	4,550	30.1	4.91	3,000	0.163	0.0055

The material excavated was a gravel and a stiff clay which was easily removed by the grader plows and would stand in a vertical face several feet high without caving or sliding.

The following table gives an itemized statement of the cost of excavation and hauling for the season of 1908.

The labor cost includes the cost of superintendence, office expenses and other all general expense. Wages for common labor were $1.75 and $2 per day of 10 hours.

The repair charges include cost of all repair parts and labor expense involved in making repairs.

Depreciation charges are based on the amount of work to be done by each piece of machinery, and the estimated salvage at the end of the job.

Supplies include oil, waste, coal, boiler compound, packing and hose. Coal cost, delivered at the dam, from $7.50 to $10.50 per ton, according to the quality.

TABLE VIII

COST OF EXCAVATION AND HAULING

Classification	Hayes Bros. grader Yardage 39,450 cu. yd. Daily ave. 391 cu. yd. Average haul 2,400 ft.		Sub-cons's. grader Yardage 37,580 cu. yd. Daily ave. 572 cu. yd. Average haul 1,200 ft.		Total Yardage 77,030 cu. yd. Daily ave 406 cu. yd. Average haul 1,800 ft.	
	Total	Unit	Total	Unit	Total	Unit
Excavation:						
Labor.......	$1,583.40	$0.0402	$1,737.21	$0.4620	$3,320.61	$0.0431
Depreciation .	599.87	0.0152	91.70	0.0024	691.57	0.0090
Repairs......	1,406.00	0.0356	171.50	0.0046	1,577.50	0.0205
Supplies.....	1,307.46	0.0332	....	....	1,307.46	0.0170
Total......	4,896.73	0.1242	2,000.41	0.0532	6,897.14	0.0896
Hauling:						
Labor.......	6,760.00	0.1715	2,902.47	0.0772	9,662.47	0.1264
Depreciation .	7.00	0.0002	8.00	0.0002	15.00	0.0002
Total......	6,767.00	0.1717	2,910.47	0.0774	9,677.47	0.1266

18. Use of Elevating Grader in Nebraska.—In the grading up of roads and the construction of road ditches in Saunders County, Nebraska, a Stroud elevating grader moved an average of 1,400 cu. yd. of sandy loam during a 10-hour day and at a cost of $28 per day for the labor of two men and 14 head of horses.

19. Use of Elevating Grader in Montana.—On the Blackfeet Project of the U. S. Reclamation Service, near Blackfeet, Montana, a New Era Reversible Elevating Grader was used in the construction of an irrigation ditch having a bottom width varying from 10 to 15 ft. Eighteen heavy mules were used to draw the grader, whose elevator belt was run by a 9-h.p. gasoline engine. The ditch was excavated principally on flat country and on hillside with slight slopes. The material excavated was principally clear loam and loam mixed with a small amount of gravel. Four men were required to operate the machine and the average excavation was 110 cu. yd. per hour, at a cost of 6 cents per yard for actual operation (not including administration and camp expense). The experience of the engineers on this project in the use of elevating graders in the excavation of ditches or

canals, showed that although animals as motive power gave good satisfaction, the greatest efficiency and economy are secured by the use of a traction engine. This type of excavator cannot be used to advantage on a ditch having a bottom width of less than 10 ft.

A Western Standard elevating grader was used in Montana, in the construction of irrigation ditches. The material excavated was a heavy sandy loam and was wasted on both sides of the ditch. On the basis of a 10-hour day, an average excavation of 900 cu. yd. was made at a cost for power and labor of 7 cents per cubic yard. Experience on this work showed that the grader was useful only in the excavation of large ditch prisms and that it was generally necessary to use some other machinery to finish the ditches and make smooth side slopes and bottoms.

20. Use of Elevating Grader in Minnesota.—The following description of the use of an elevating grader in the construction of a drainage ditch is taken from Bulletin No. 110 of the Northwest Experiment Farm of the University of Minnesota.

The machinery of the grader was operated by a 12-h.p. gasoline engine. A disc plow with a diameter of 24 in. and set at an angle of about 5 in. was used to elevate the earth on a 30-in. belt. The elevator had a length of 22 ft. with a maximum extension to 30 ft. The elevator and plow are supported from a steel frame, which is mounted on two trucks, the front truck having a wheel width of 6 ft. and the rear truck a wheel width of $9\frac{1}{2}$ ft. The rear wheel on the elevator side had a tire width of 20 in. and the other three wheels a tire width of 10 in.

The machine was drawn by 16 horses, four in the lead team and six in each of the front and rear teams. A driver was used for each team and one man operated the elevating machinery. The time of turning the grader averaged one minute. The average speed of the machine was 1.3 miles per hour for a working day of 10 hours. The average fuel consumption was 12 gal. of gasoline per 10-hour day.

It was found that the minimum cross-section of ditch, which could be excavated with the elevating grader was one having a bottom width of 8 ft., a depth of 2.5 ft. and side slopes of 1 to 1. The greater the bottom width, the deeper the machine can excavate, but the narrower the berme becomes. It required 25 ft. clear space along each side of the ditch for operation and a length of 100 ft. at the end of the ditch for turning.

On a level stretch with a length of three-fourths of a mile and

where the earth was dry and free from obstructions, an average daily excavation of 1,200 cu. yd. was made. Of this amount 200 cu. yd. was outside of the required cross-section of the ditch, leaving 1,000 cu. yd. of pay excavation.

21. **Use on Chicago Drainage Canal.**—During the latter part of the year 1894, while waiting for the completion of the bridge conveyors which were to be used in the excavation of sections K and I of the Chicago Drainage Canal, and to keep up with the contract requirements as regards monthly progress, the earth to a depth of about 5 ft. over the entire area of the two sections was excavated and removed with elevating graders and dump wagons.

There were five New Era graders and 35 Austin Dump Wagons used on this work. Each grader was operated by 12 horses and three men and served by seven dump wagons with three horses and a driver to each.

The soil excavated was a soft clayey loam and the average haul was about 500 ft.

The average excavation[1] for each grader was 500 cu. yd. for a 10-hour working day. Records kept on Section K during August and September, 1894, gave the average output as 490 cu. yd. and 515 cu. yd. per 10-hour day, respectively. On Section I the average output for each grader for September, 1894, was 485 cu. yd. per 10 hours. The total time consumed on both sections was 123 10-hour days, and the average daily force was 50.4 men, 41.9 teams, 22.3 wagons and 3.1 New Era graders. The average output per day worked for each quarter was 508 cu. yd. The use of these graders on the top-soil excavation of these two sections was very satisfactory.

22. **Résumé.**—The elevating grader is most efficient in the construction of shallow highway ditches, the upper sections of large ditches and lateral ditches, with bottom width not less than 10 ft.

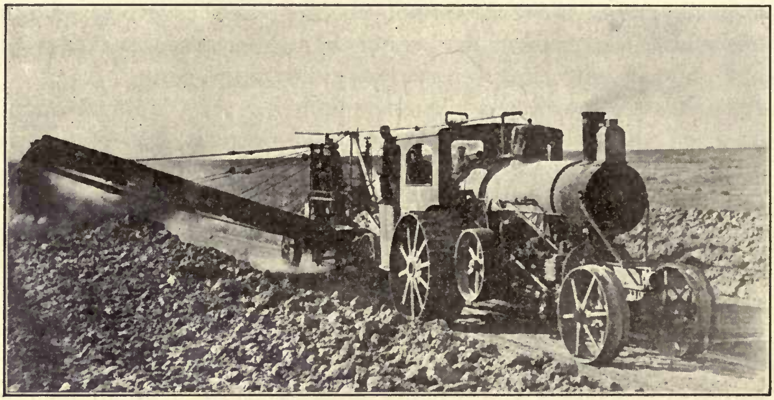
The soil conditions must be favorable for the satisfactory operation of this excavator. Very loose and light soils cannot be raised by the plow, and wet sticky, gumbo soils work with difficulty. A soil in which there are roots or boulders is unsuitable for grader work.

The gasoline engine should be used to operate the belt conveyor. The traction engine for motive power can be used to better advantage than animal power where the soil conditions are suitable. It has been found in the use of the grader in irrigation work in the

[1] The Chicago Main Drainage Channel. C. S. Hill.

isolated dry and hot sections of the west that horses or mules are difficult to secure and keep. Light and loose sandy soils will not stand up under the heavy weight of a traction engine, while some dense clayey soils pack so hard under the engine wheels as to make their excavation difficult.

It may be safely assumed that a standard elevating grader under average conditions will move 500 cu. yd. of earth 500 ft. in 10 hours.



Traction Engine and Elevating Grader Excavating Irrigation Canal.
Figure 21.

The cost of operation will average about 10 cents per cubic yard and to this should be added from $1\frac{1}{2}$ to $2\frac{1}{2}$ cents for interest on investment, depreciation, repairs, etc.

23. Bibliography.—For additional information, consult the following references:

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2. Steam Excavating and Grading Machine; Engineering News, August 15 1901. Illustrated, 1,100 words.

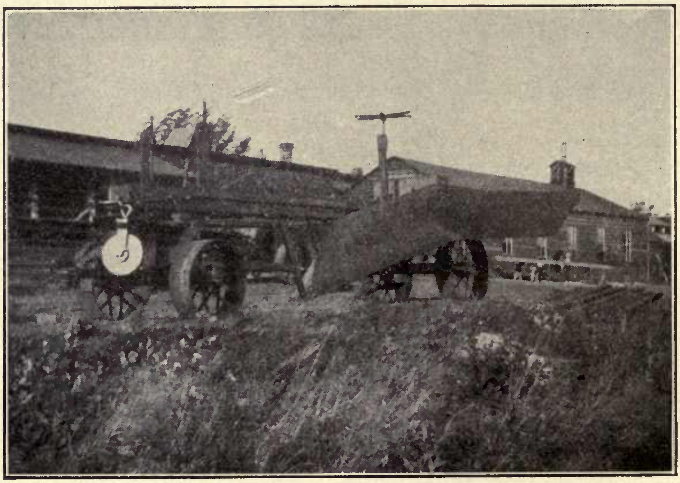
CHAPTER IV

CAPSTAN PLOWS

24. Complete Outfit.—A capstan plow outfit consists of the plow and two capstans, each of which can be readily mounted on a pair of trucks for transportation and two large cabins of a single room each, mounted on wheels; one cabin for a dining room and the other for sleeping quarters. Six or eight men and 16 to 18 horses are used to operate a capstan plow outfit.

25. Field of Work.—The construction of small open ditches, such as are required for the drainage of small sloughs or swamps and as laterals in a large drainage system, has been commonly done in the middle West by means of a capstan plow.

26. General Description.—This type of excavator consists of a large plow, hung from a framework mounted on two trucks and thus



Capstan Plow.
Figure 22.

easily moved from place to place. A typical make of capstan plow is shown in Fig. 22.

26a. The Plow.—The plow has a cast steel point to which are fastened sloping sides of heavy planking. These sides have a slope

upward and outward so as to excavate side slopes of 1 to 1. At the rear ends of the sides of the plow are fastened wings made of heavy planking. The wings are vertical planes with horizontal top and bottom edges, and flare back from the sides of the plow. The cutting edge is fastened and braced to a long beam to the front end of which is fastened the ropes or wire cables which lead to two capstans set ahead of the plow and one at either side of the ditch line. A long pole projects from the capstan and to the outer end is hitched several teams of horses. These are driven in a circular path around the capstan, the drum of which revolves and winds up the rope and cable, drawing the plow through the earth. By working either one or both capstans together, the plow may be moved to one side or straight ahead.

26b. Sizes of Ditch.—There are two sizes of capstan plows in general use, one which makes a ditch 16 in. wide on the bottom, 8 to $9\frac{1}{2}$ ft. wide on top, and 3 ft. in depth, and a larger size which makes a ditch with a cross-section at the bottom of 30 in., a top width of 9 to 11 ft., and a depth of 4 ft. It will be seen from the above data that the side slopes are about 1 to 1.

26c. Cost of Operation.—The following would be the daily cost of operation of a capstan plow outfit used for the cutting of a drainage lateral ditch through loam and clay under average working conditions. The size of plow would be the smaller as described in Article 22b.

Labor:

1 foreman,	$4.00	
4 laborers, @ $1.50,	6.00	
1 cook, @ $35.00 per month,	$1.40	
8 teams, @ $2.00,	16.00	
Total,		$27.40

Fuel and Supplies:

$\frac{1}{4}$ cord of wood for cooking,	$1.00	
Rope, oil, bolts, etc., for machine,	0.50	
Total,		$1.50

Board and Lodging:

Provisions, groceries, canned goods, supplies for the feeding and care of six men,	$5.00

Miscellaneous:

Interest, depreciation and repairs,	\$1.00
Total cost of a day's operation,	\$34.90

Average day's excavation is about	60 rods of ditch
Cost of excavation; \$34.90÷60=	\$0.58 per rod.
Contract price,	\$1.00 per rod.

27. **Résumé.**—The capstan plow has been generally used in the middle west in the construction of small drainage ditches. It is popular with the average farmer because the work is easily, quickly, and cheaply done. Where the surface of the ground has a uniform slope, this excavator will make a small ditch satisfactorily, but for undulating or uneven land it is useless, unless the surface is previously graded off.

As a general thing capstan plow ditches are too small and where the slope is light, they soon fill up and become useless. The author has seen on the valley lands of Iowa and South Dakota, many such ditches which after three or four years use, were nearly filled up with débris, silt, weeds, Russian thistle, tumble weed, etc.

The capstan plow can only be used efficiently and satisfactorily for the excavation of small lateral ditches for irrigation and drainage systems, where the slope of the ground surface is uniform and sufficiently large to give a flushing velocity with the ditch running half full.

CHAPTER V

STEAM SHOVELS

28. Field of Work.—The steam shovel has been used extensively since 1865, in the excavation of all classes of material and on all kinds of earthwork. The building of the transcontinental railroads soon after the close of the Civil War brought about a demand for power shovels, and at once several companies were making shovels of various types. The principles of operation of all makes of shovel are the same, but the different manufacturers vary the design and construction of the parts and claim therefore special operating advantages.

The steam shovel was originally used in making the cuts for railroad work, but its uses in recent years have greatly multiplied until at the present time it is used for the excavation of ditches and canals for irrigation, drainage and water-power projects, sewer and water trench construction, the grading of streets, the building of reservoir embankments, earthen dams, etc. Where the job is of sufficient size to warrant its use, and the soil is firm and hard enough to support it, the steam shovel is a very efficient and economical type of excavator.

29. Classification.—Steam shovels may in general be placed in two classes:

First, those where the machinery is mounted on a fixed platform and the sphere of operations is limited to an arc of about 200 degrees at the head of the machine.

Second, those where the machinery is mounted on a revolving platform, and the sphere of operations is within a circle the center of which is the middle of the machine.

The first class may be divided into three types, depending on the manner of supporting the platform.

(a) Machines mounted on trucks of standard gage, used entirely in railroad construction.

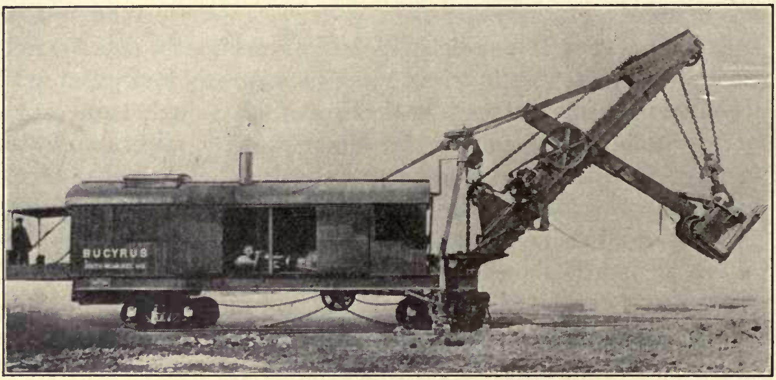
(b) Machines mounted on trucks with wheels other than standard gage and used in railroad construction or any other class of excavation.

(c) Machines mounted on trucks with small, broad tired wheels and used in railroad, street and any other class of construction.

The second class is made only in the smaller sizes and the truck is mounted on small, large, flat-tired wheels for transit over ordinary roads. These light revolving shovels are especially adapted for the excavation of small, scattered railroad cuts, street grading, cellar, trench and ditch construction.

The machines of type (a) are generally preferred for railroad work. A wooden or steel car-body is supported on two four-wheel trucks of standard gage. The crane, which is generally made of steel, is so arranged that it can be lowered to pass under overhead bridges and through tunnels.

The shovels of type (b) were the first built and are still used on general work. They are mounted on a side wooden or steel frame or car-body, which is supported on four small wheels of 7 ft.



Bucyrus Seventy C Steam Shovel.
Figure 23.

to 8 ft. gage. Great stability is thus given to the machine by placing it near the ground with a side base. For transportation, when near a railroad, the machine is placed on a flat car and the boom removed and placed on a separate car. Away from a railroad line, the machine can be readily dismantled and shipped in sections by wagons or boat. This type of shovel, on account of its portableness and quick adaptability to all kinds of work in any locality, makes it desirable for general use.

These three types differ principally in their method of support, but otherwise are similar in their details of construction and opera-

tion. The construction of the first and second classes will be given separately in the following article.

30. **Construction. First Class.**—The general arrangement is the same in all makes of steam shovel. On the platform of the car-body is placed the operating machinery and power equipment, the boiler at the rear end, the engines near the center and the A-frame and boom at the front end of the car. Fig. 23 shows a Seventy C Bucyrus Steam Shovel.

CAR-BODY

The trucks, whether of standard railroad type or special construction, are generally placed near the ends of the car, nearly under the boiler on the rear end and under the A-frame on the front end. For type (a) of this class, the trucks are generally the extra heavy M. C. B. standard with all steel diamond frames. The inside axles of both trucks are chain connected to sprocket wheels operated by the engine, thus furnishing the propelling power for moving the shovel in either direction along the track.

The frame, supported by and pivoted to the trucks, is made up of steel I-beams and channels well braced longitudinally and transversely and strongly riveted and bolted together. The frame is floored with heavy planking, usually 3-in. oak or yellow pine, upon which rests the power equipment. The size of the car-body varies with the capacity of the shovel, an average size such as a 75-ton shovel, has a length of 40 ft. and a width of 10 ft. The ends of the frame are generally equipped with automatic couplers of an approved type, so that the machine may be coupled into a train.

As the car-body is subjected to severe and rapidly repeated strains, it is necessary that it shall be very rigidly constructed at the front end, under the A-frame supports, and the turntable. Some manufacturers use oak timbers between the steel members, claiming that the wood acts as a cushion to resist the continual twisting and wrenching strains. Doubtless the wood does add a certain amount of elasticity to the frame and tends to reduce the tendency to shear off bolts and rivets and to crystallize the steel. The wood should be of the most durable variety, such as white oak.

The car-body supports a framework of timber or steel upon which is applied a sheathing of wood or corrugated steel to form the sides and roof of a car. This is necessary to protect the machinery from

climatic conditions. In the later types of dredges, sliding doors are provided, so that light and ventilation may be had in pleasant weather.

BOILER

The boiler may be either of the vertical type with submerged flues or of the horizontal locomotive type. The former is more economical of floor space, but the latter is more economical in the use of fuel, and for this reason is generally used in the larger machines. The boiler should be of ample capacity, as it is often worked to the limit with the throttle wide open. Steam pressure is generally maintained at about 100 lb. with a blow-off at from 125 to 150 lb.

Water should always be supplied to the boiler through an injector by means of a feed-pump. Water is stored in a sheet-iron tank located in a rear corner of the platform. The tank usually has a capacity of about 1,000 gal. or enough for one-half day's operation of the machine. At the rear end of the platform is placed a bin, tank or open box to hold the fuel for the boiler or engine. Coal and wood are generally used for steam boilers, while gasoline or kerosene is used when a gas engine supplies the power. The water may be supplied to the storage tank by siphoning or pumping it out of the tender of a locomotive, a tank car, or a tank wagon.

ENGINES

The engines are either of the vertical type with a single steam cylinder or of the horizontal type with double steam cylinders. The engines control the three principal operations of the shovel, hoisting, swinging, and thrusting. In some of the older types of shovels, all three operations are controlled by one engine. This type has three drums mounted on one shaft, the hoisting drum in the center and the swinging drums on each side. The latter are reversed and operated by the same lever. The drums are actuated and controlled either by positive gearing or friction clutches. The former is slow in operation and subjects the machinery to great jarring and severe shocks in digging hard material. The latter is quick and smooth in operation, and gives a minimum of shocks in hard material, but is liable to bind through overheating of the friction surfaces. To alleviate this source of trouble, the diameter of the friction drums should be at least twice that of the cable drums. The positive gearing generally has a longer life and requires fewer repairs than the friction clutch, but the latter is the more popular at the present time

on account of its rapidity and smoothness of action. The single shaft with its three drums, rotates continuously in one direction under the action of a large steel gear driven by a steel pinion on the engine shaft. The hoisting chain passes over a sprocket, at the top of the mast or the foot of the boom, and this revolves an axle to which another sprocket wheel is fastened. The latter operates an endless chain which revolves a drum placed on the upper side of the boom near the dipper handle. This drum is controlled by a friction clutch and operated by the cranesman. In the older types of machine a chain is attached to the end of the dipper handle, and wound around the drum. The rotation of the drum raises and lowers the dipper handle. In later types, a rack on the bottom of the dipper handle moves a pinion on a shaft which is operated as described above.

The recent types of steam shovel use a small independent engine to thrust the dipper into the bank, placed on the upper side of the boom, and is of the double-cylinder, horizontal type. It operates a set of gears, which revolve a shaft on which is set a steel pinion feeding into a steel-toothed rack on the bottom side of the dipper handle. The engine may be either reversible or controlled by a friction clutch. With the use of the former type, the dipper handle is always actuated and controlled by the engine, while with the latter type, the release of the friction allows the dipper and handle to lower by gravity.

Instead of having the swinging of the boom actuated from the main engine, some makes of steam shovel use an independent swinging engine. This is usually a double-cylinder horizontal, reversible engine of less power than the main or hoisting engine. A chain or cable passes around the swinging circle and is wound around the drum of the engine, starting from the two ends of the drum in opposite directions.

The size of the engines vary with the type used and the capacity of the shovel. They should be made of ample power for use in the hardest and toughest material. The power of an engine depends on the size of its cylinders, varying from 6 by 8 in. to 13 by 16 in. These engines are subjected to almost continuous shocks and vibratory strains and should be made of the very best and strongest materials. The more important parts such as the shafts and gears should be of the best tool and cast steel, respectively.

BOOM

The boom is a simple beam made in two sections, separated far enough to allow for the free passage of the dipper handle. It may

be constructed of wood reinforced with steel plates or entirely of steel. It is made narrow at the ends and wide near the center where the dipper handle rests. The greatest strain is at this point. It is made of such length as to reach 14 to 20 ft. above the track or ground surface, and to swing with a radius of from 15 to 20 ft., through an angle of from 180 to 240 degrees. The lower end of the boom rests on the swinging circle which is pivoted to the front end of the platform. The boom revolves with the swinging circle. Its upper and outer end is connected to the top of the A-frame with steel rods or bars.

The hoisting chain or cable passes from the hoisting drum to the fair lead or sheaves just below the turntable, then up over the sheave near the foot of the boom and thence along the boom to the sheave at the outer end of the boom, and thence to the shovel at the outer end of its handle. The revolution of the hoisting drum lets out or draws in the chain or cable and thus lowers or raises the shovel.

A-FRAME

This is a frame made up of heavy steel bars with timber reinforcement or entirely of structural steel posts. The feet of the posts are supported on each side of the platform just back of the turntable. The top of the frame carries a pivoted cast-steel head block to which is fastened the rods or bars from the outer end of the boom. The A-frame is given a slight inclination toward the boom and is made several feet shorter. The height of the boom when it is lowered, must be less than the overhead clearance, where a shovel has to pass through tunnels or under bridges, or in railroad and street work.

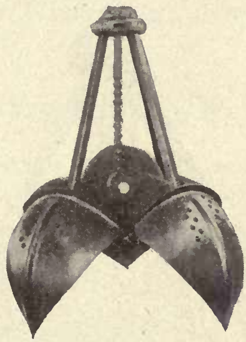
DIPPER HANDLE

The handle to the lower end of which is attached the dipper or shovel, is generally made of a single timber of white oak. Upon its lower side is fastened the toothed rack which moves over the pinion on the upper side of the boom. The operation of this pinion was described in the section entitled "Engines." The upper edges of the handle are reinforced with steel angles or bent plates.

DIPPER

The shovel or dipper is made in the form of a scoop with closed side, open top and a hinged door for the rear or bottom. It is made of heavy steel plates strongly reinforced at top and bottom with

steel bars. The top or front edge of the dipper is provided with a cutting edge of flange steel for soft material, or of heavy forged steel teeth for hard material. These teeth can be readily unbolted for sharpening or repairs. The bottom of the bucket is of heavy steel hinged to the rear side of the dipper, and closed by a spring-latch on the front side. A small line leads from the door to the side of the



CAPACITY		HEIGHT		DIAMETER		WEIGHT
Cu. Yd.	Cu. Ft.	Closed	Open	Closed	Open	Price
½	13½	5′-10″	6 - 6″	4 -6″	5′-7″	1750 lbs. **$472.00**
¾	20¼	7′- 4″	7′-10″	5′-6″	7′-0″	3450 lbs. **$650.00**
1	27	8′- 0″	8′-10½″	6′-0″	7′-1″	4250 lbs. **$680.00**
1¼	33¾	8′-3½″	9′- 2½″	6′-3″	7′-3″	4775 lbs. **$780.00**
1½	40½	9′- 5″	10′- 0½″	6′-6″	8′-6″	6800 lbs. **$880.00**
2	52	10′- 0″	11′- 2″	7′-0″	8′-9″	8400 lbs. **$1140.00**

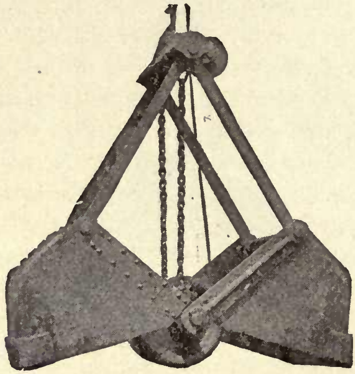
Browning Orange-peel Buckets.
Figure 24.

boom where the cranesman stands. When the filled dipper is over the car or wagon, a jerk on the line by the cranesman opens the latch and causes the bottom to drop, releasing the contained material.

Dippers vary in size from $\frac{1}{2}$ cu. yd. to 6 cu. yd. and require corresponding machines weighing from 10 to 130 tons.

The shape of the dipper and the character of the cutting edge should depend on the character of the material to be excavated. Teeth

should be used as a cutting edge for hard material, while they cause considerable trouble in dumping in removing sticky clay. For sand, gravel and the average clay and loam, a wide smooth cutting edge should be used. A large, wide dipper should be used when the material is filled with large stone or boulders. For soft, loose material such as sand, loose gravel and dry earth, the shovel should be deep



Capacity		Height		Length		Width	Weight Price No Shoes	Weight Price With Shoes
Cu. Yd.	Cu. Ft.	Closed	Open	Closed	Open			
½	13½	5'-8"	6'-9"	5'-0	6'-0"	2'-5"	2100 lbs. **$350.00**	2300 lbs. **$375.00**
¾	20¼	6'-1"	7'-2"	5'-4"	6'-7"	3'-1"	2500 lbs. **$400.00**	2750 lbs. **$450.00**
1	27	6'-5"	7'-7½"	5'-8"	7'-2"	3'-1"	2600 lbs. **$425.00**	2850 lbs. **$475.00**
1½	40½	7'-2"	8'-5¾"	6'-4"	8'-0"	3'-7"	4500 lbs. **$475.00**	4900 lbs. **$525.00**
2	54	7'-8"	8'-11½"	6'-8"	8'-7"	4'-1"	4800 lbs. **$550.00**	5875 lbs. **$600.00**
3	81	7'-9"	8'-7"	6'-8"	9'-8"	5'-1"		8150 lbs. **$850.00**

Browning Clam-shell Buckets.
Figure 25.

with a cross-section nearly square. A wide, shallow-mouthed dipper is the best shape for the excavation of cemented gravel, hard dry materials or wet clay. The bottom of the dipper should be slightly larger than the top, to facilitate the dumping of sticky material. A great deal of time is often lost in cleaning the dipper when it is excavating sticky soils such as gumbo. A sprinkling hose is very useful

for removing this sort of material from the sides of the dipper, and to prevent its adhering.

The dipper is fastened to the handle by means of heavy forged arms and braces. A hinged bail connects the top of the dipper with the hoisting line. In some makes of shovel this line is fastened directly to the top of the bail, but generally it passes through a sheave in the top of the bail and is carried up and fastened to the boom, near its outer end.

TYPES OF BUCKETS

Several kinds of dippers or buckets are used with the steam shovel. The dipper, described previously is the type generally used in the excavation of ditches and canals. The ordinary type of dipper is shown in Fig. 26. When loose sand and gravel are to be excavated, the clam-shell or orange-peel buckets are efficient. Fig. 24 gives the details and dimensions of a standard make of clam-shell bucket, while Fig. 25 gives the same information for the orange-peel bucket.

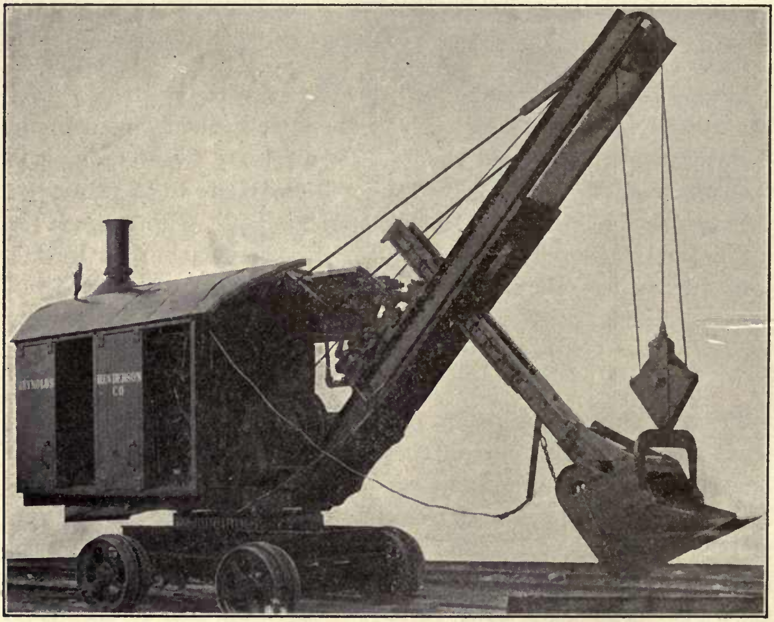
JACK-BRACES

The swinging of the boom, dipper and handle from side to side tends to tip the front end of the car. To prevent this, jack-braces are placed on the sides of the car-body at the feet of the A-frame. These braces are of heavy cast steel and are attached to the platform at their upper ends by means of cast steel hinges or sockets. The lower ends carry screw jacks which can be easily raised and lowered to get a bearing on the ground surface. The lower ends of the braces are connected to the under side of the car-body by heavy bars or rods. These are also hinged so that the whole brace may be swung back against the car-body, when not in use.

30a. Revolving Shovels. Second Class.—The revolving shovel is built on lines similar to the revolving locomotive crane which has been used extensively in recent years. A typical revolving shovel as made by the Bucyrus Company of South Milwaukee, Wis., is shown in Fig. 26.

As this type of shovel is intended for easy transportation over roads, and for slight, rapid work, the supporting base is small in area. The lower or truck platform is made up of a rectangular frame of steel I-beams and channels, strongly braced and riveted together. This platform rests on two steel axles, the front one pivoted and the rear

one fixed in position. The rear axle carries a sprocket wheel, which is connected to the engine with a chain, providing for the traction of the machine under its own power. By turning the front axle the direction of the machine's movement may be governed. The wheels are small in diameter, of heavy solid wood or open steel and provided with wide tires. Railway wheels of standard gage are provided when the shovel is to be operated on a railroad track. Upon the top



Bucyrus Revolving Steam Shovel.
Figure 26.

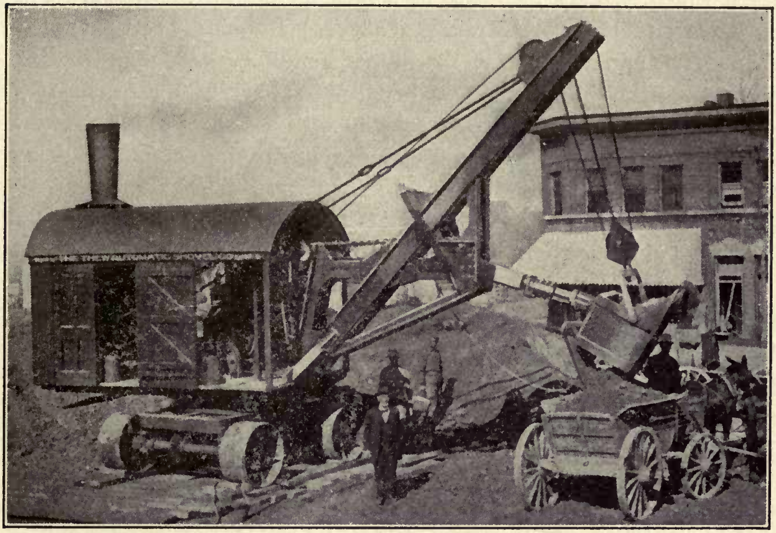
of the steel frame is fastened a large, heavy steel casting which comprises a circular gear, the roller track and the central journal or gudgeon, which supports the revolving frame.

The upper frame carries the machinery and the boom and corresponds to the car-body of the first class of shovel. This frame is made up of steel members strongly framed together and covered with a floor of heavy planking. The bottom of the frame has a heavy cast steel socket which fits over the journal of the lower frame. The whole operating mechanism of the shovel can rotate in a complete circle about the lower truck frame.

POWER EQUIPMENT

Ordinarily the revolving shovel is provided with a steam-power equipment, consisting of a vertical boiler and engines for hoisting, swinging and thrusting. The hoisting and swinging engines are usually mounted on a single steel base, while the thrusting engine is placed on the upper side of the boom.

The hoisting engine is placed on the front end of the platform near the pivoted foot of the boom. It is reversible and has a single drum



Thew Revolving Steam Shovel.
Figure 27.

for the ordinary dipper, but may be equipped with two drums when a clam-shell or orange-peel bucket is to be used.

Behind the hoisting engine is the swinging engine, which is reversible and geared to a vertical shaft, at the lower end of which is a steel pinion which operates on the circular gear or rack on the truck frame.

The thrusting engine in several makes is similar to the one described above for the shovels of the first class. See Article 26. One make, the Thew Automatic Steam Shovel, uses a unique method of thrusting or crowding the dipper. The dipper arm is hinged to a carriage or trolley, which slides horizontally along a trackway. As the carriage moves forward the center of rotation of the dipper is changed and this gives a prying action. The sliding carriage is made up

of heavy steel with removable friction-shoes, and is operated by a wire cable moved by a drum geared to the hoisting engine. The movement of the trolley is controlled by the cranesman manipulating a throttle lever. At each end of the horizontal track, the trolley strikes a "trip," which automatically cuts off the steam, thus preventing accidents.

Another unusual feature of this shovel is the construction of the dipper handle. This is made of steel and in two sections, the lower part telescoping into the upper and is held in position by a spring latch which engages the teeth of a rack on the lower section. The spring latch is operated by means of a lever manipulated by the cranesman. The upper section of the dipper handle is made short so that the upper part of the boom may be laced to provide lateral stiffness.

The combination of trolley trackway with the short dipper handle, resulting in the securing of a considerable prying action, is very serviceable in the excavation of tough and hard soils.

Figure 27 shows a Thew Automatic Steam Shovel excavating the basement of a large building.

Gasoline power can be used to great economic advantage where coal is high in price and inaccessible. A gasoline engine is mounted on the rear of the platform and belt-connected to the engines.

31. Electric Operation.—In a large city where electric power is cheap or along the lines of large power plants, electric power can be used advantageously for the operation of the steam shovel.

The best field at present for the operation of electric shovels is in connection with electric traction railways, where the power is at hand and obtained at a low cost. In this case the shovel is mounted on standard trucks and is either hauled or self-propelling. Where electric power can be bought at 2 cents per kw.-hour, the cost of operation is about one-half that of steam shovels.

The power equipment of an electric shovel consists of a motor of from 50 to 200 h.p. to operate the hoist, a motor of from 25 to 80 h.p. to operate the swinging mechanism, and a motor of from 25 to 80 h.p. to operate the thrust. The various sizes of motors for the various capacities of shovels is given in the following table.[1]

The hoisting and swinging engines are mounted directly on the rear of the platform of the shovel and are geared to the drums through reducing gears. The thrust motor is mounted on the upper side of the boom, and geared to the pinion gears through proper reducing gears.

[1] From "Electrically Operated Shovels," by W. H. Patterson. Electric Journal, Nov., 1910.

These motors are generally of the crane or mill type with high torque characteristic and are reversing. They may be either for direct or alternating current.

TABLE IX

SIZES OF MOTORS

Weight of shovels, tons	Size of dipper, cu. yd.	Horse-power of motors		
		Hoist	Swing	Thrust
30	1	50	30	30
35	$1\frac{1}{4}$	50	30	30
35	$1\frac{1}{4}$	60	30	30
35	$1\frac{1}{4}$	75	35	35
42	$1\frac{1}{2}$	75	30	30
65	2	100	35	35
95	$3\frac{1}{3}$	150	50	50
100	4	200	80	80

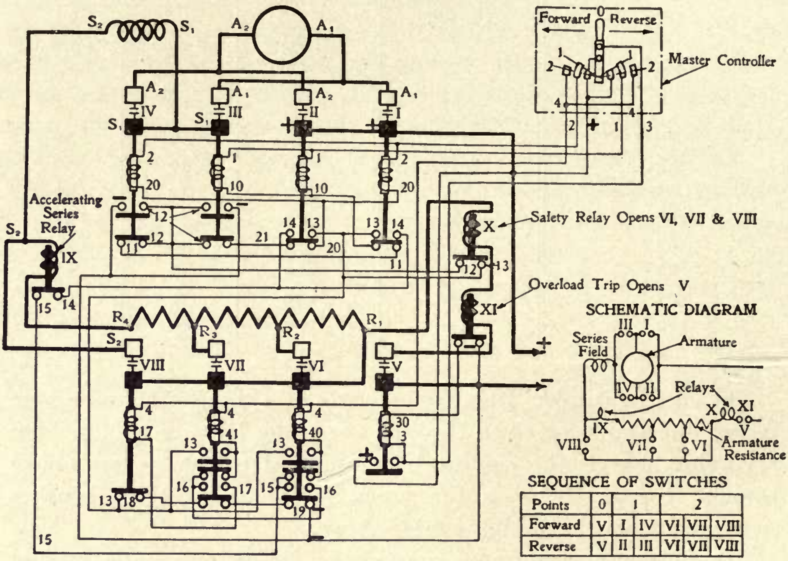
The current is taken from trolley wires or a transformer on a high power line and is received through the truck by wire cables. On revolving shovels the current is transmitted to the motors above through copper rings on the truck frame and carbon brushes suspended from the swinging table above.

The following diagram of connections for an automatic magnet switch control and description are given by W. H. Patterson in the Electric Journal of November, 1910.

"The master controller has two running positions in either direction. The first position connects the motor to the line with all the armature resistance in series, the second position energizes magnet switches *VI*, *VII* and *VIII* through the accelerating relay *IX*. These switches short-circuit the resistance in sections, each successive step being delayed until the current in the accelerating relay falls below a fixed value. The various positions are interlocked, so that it is impossible for the switches to close in the wrong order. The master controller can be thrown from full speed forward to full speed reverse, without damage to the motor, as the starting switches for either direction cannot close until all the control switches are opened and full armature resistance has been connected into the circuit. The reversal is thus made in the least possible time consistant with the safety of the motor.

"In case of an overload on the motor, safety relay *X* opens, breaking

the control circuit of switches *VI*, *VII* and *VIII*, and cutting all the armature resistance into the circuit. The motor will then exert its full starting torque continuously until the overload is removed, where the resistance will be automatically short-circuited again. This feature of the control is especially valuable for shovel work, as frequently a stone or log may be dislodged by a steady pull when it cannot be moved by a sudden jerk. If the overload current exceeds the value for which the overload relay *XI* is set, the line switch *V* opens, disconnecting the motor from the line. On



Points	0	1		2		
Forward	V	I	IV	VI	VII	VIII
Reverse	V	II	III	VI	VII	VIII

Wiring Diagram for Electrically Operated Shovel.
Figure 28.

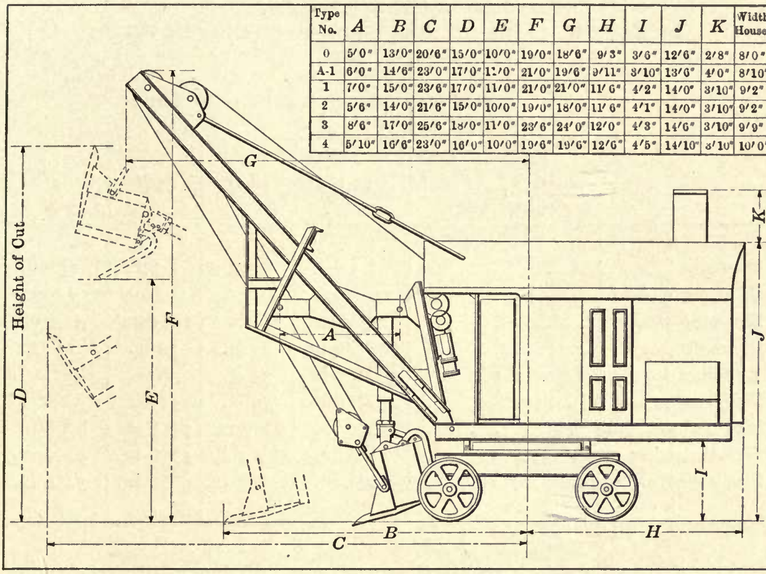
moving the master controller to the off position, magnet switch *V* is reset, and the motor may be started again in the usual way."

The above description of the working of the automatic magnetic controller used with a series overloaded relay explains the recent devices used to overcome the objections to electrically operated shovels. The sudden stopping of the dipper in the bank, due to cutting too deep or striking an obstruction, tends to stall the motor and burn it out. The use of the apparatus described in the above quotation satisfactorily protects the motor against such overloads by cutting resistance into the circuit when the current exceeds a fixed value.

"The motor driving the thrust may be operated either by a drum controller or by an automatic magnet control. The motor and its controller must be of such a design that the motor will be able to develop a heavy torque for short intervals of time while standing still, or rotating very

slowly. Its duty is to jam the dipper against the bank and hold it there while the hoist operates. As soon as the dipper strikes the bank, the thrust motor ceases to revolve, except very slowly, but must still exert full torque in order to keep the dipper against the face of the cut. Its characteristics should, therefore, be such that it may be stalled frequently for a minute or more at a time and still keep developing full-load torque without injury."

"The motor driving the swinging boom may be operated by hand control if provided with a magnetic brake to stop the motor quickly and keep the circuit breaker from opening if the motor is reversed quickly; or may be operated by automatic control without a brake."



Type No.	A	B	C	D	E	F	G	H	I	J	K	Width House
0	5′0″	13′0″	20′6″	15′0″	10′0″	19′0″	18′6″	9′3″	3′6″	12′6″	2′8″	8′0″
A-1	6′0″	14′6″	23′0″	17′0″	11′0″	21′0″	19′6″	9′11″	3′10″	13′6″	4′0″	8′10″
1	7′0″	15′0″	23′6″	17′0″	11′0″	21′0″	21′0″	11′6″	4′2″	14′0″	3′10″	9′2″
2	5′6″	14′0″	21′6″	15′0″	10′0″	19′0″	18′0″	11′6″	4′1″	14′0″	3′10″	9′2″
3	8′6″	17′0″	25′6″	18′0″	11′0″	23′6″	24′0″	12′0″	4′3″	14′6″	3′10″	9′9″
4	5′10″	16′6″	23′0″	16′0″	10′0″	19′6″	19′6″	12′6″	4′5″	14′10″	3′10″	10′0″

Diagram and Dimensions of Thew Steam Shovel.
Figure 29.

In swinging the boom with the dipper full, it has been found difficult to gradually stop the boom without doing injury to the structural parts of the front of the machine. In the case of a steam shovel, the steam is used as a cushion to counteract the momentum of the swinging boom. In an electric shovel some appliance such as a set of springs operating a solenoid brake, must be used.

Where electric power is accessible and inexpensive, the cost of operation of an electric shovel is less than that of a steam shovel, for the following reasons: it requires less lador for operation, no fireman is required; the hauling of coal and water is eliminated; its

economy of power is greater, as the power is used only when in operation, in the case of a steam shovel, the steam must be kept up continuously; the operation is quieter, steadier and quicker than that of a steam shovel.

Figure 29 gives a diagrammatic view of a Thew Automatic Steam Shovel. The table in the upper right-hand corner gives the dimensions of the various sizes.

The following table gives the size of the various parts of the Bucyrus revolving shovels.

TABLE X

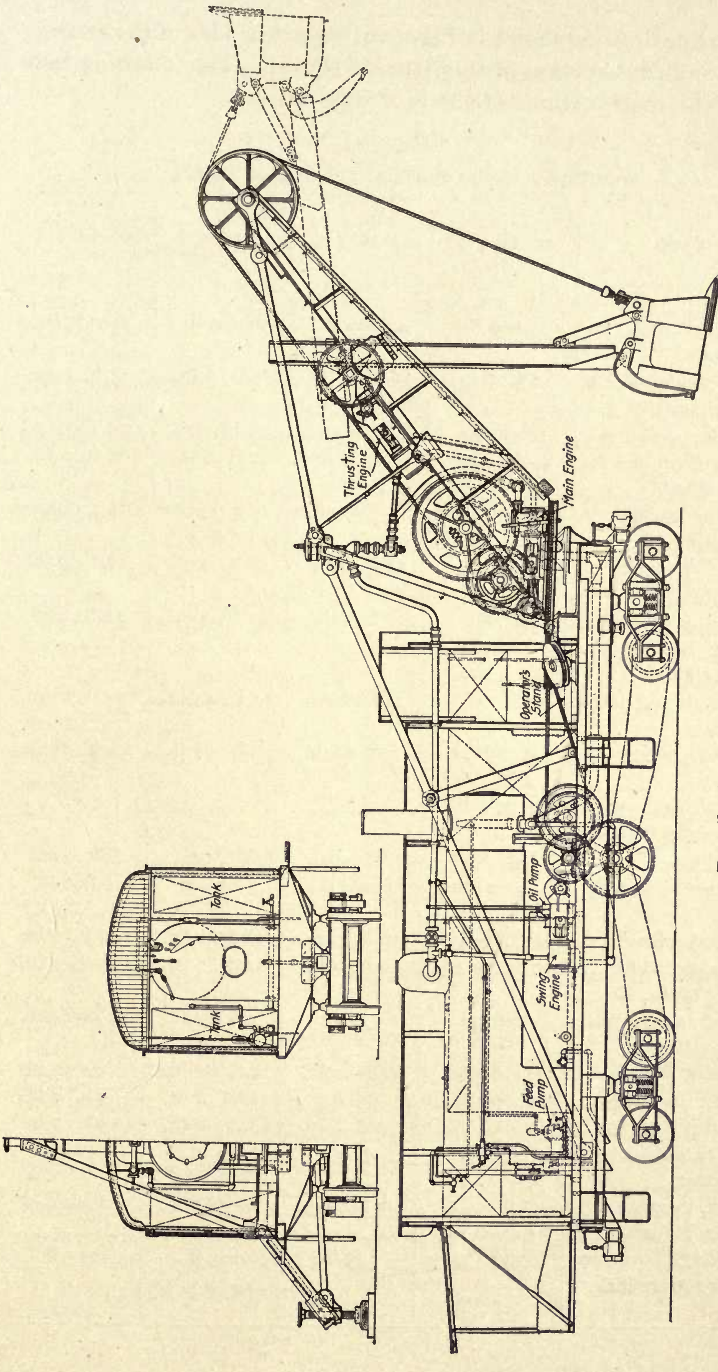
SPECIFICATIONS OF BUCYRUS REVOLVING SHOVELS

Item	Class of shovel			
	14 B	18 B	25 B	32 B
Dipper	5/8 yd.	7/8 yd.	1 yd.	1¼ yd.
Working weight	15½ tons	21 tons	25 tons	35 tons
Shipping weight	14 tons	18 tons	22½ tons	32 tons
Clear lift	10 ft. 6 in.	11 ft.	12 ft.	13 ft.
Width of level floor shovel will cut	30 ft. 6 in.	33 ft.	36 ft.	36 ft. 6 in.
Width of cut at 8 ft. elevation	47 ft. 6 in.	50 ft.	52 ft.	54 ft.
Size main engines	5×6 in.	6×7 in.	7×8 in.	8×8 in.
Size thrusting engines	4×5 in.	4½×5 in.	5×6 in.	5×6 in.
Size swinging engines	4×5 in.	4½×5 in.	5×6 in.	5×6 in.

32. Atlantic Steam Shovel.—The American Locomotive Company, several years ago, in an endeavor to secure the highest efficiency in steam-shovel design, devised the Atlantic steam shovel. This machine is now (1913) manufactured and sold by The Bucyrus Company of South Milwaukee, Wisconsin.

This machine uses the wire rope instead of chain for hoisting. The hoisting engine is placed upon a single casting, which serves also as the swinging circle at the foot of the boom. By this arrangement, the hoisting is done directly with one sheave instead of the general indirect hoisting with from five to seven sheaves. Thus the friction of the chain and of from four to six sheaves is eliminated.

The removal of the hoisting engine from the platform allows the use of a larger boiler with greater steaming capacity.



Detail Views of Atlantic Steam Shovel.
Figure 30.

The line drawing shown in Fig. 30 gives a clear idea of the arrangement and construction of the Atlantic shovel. The following table gives the specifications of the four sizes made.

TABLE XI

SPECIFICATIONS OF ATLANTIC STEAM SHOVEL

Class	25-11-1-¼[1]	45-16-2-½	60-17-3-½	80-18-4-½
Effective pull on dipper.	25,000 lb.	45,000 lb.	60,000 lb.	80,000 lb.
Clear height of lift above rail.	11 ft. 6 in.	16 ft. 6 in.	17 ft. 0 in.	18 ft. 6 in.
Capacity of dipper..	1¼ cu. yd.	2 ½ cu. yd.	3½ cu. yd.	3 to 5 cu. yd.
Width of cut at 8 ft. elevation.	42 ft. 0 in.	56 ft. 0 in.	62 ft. 0 in.	64 ft. 0 in.
Working speed per minute.	3 to 5 dippers	3 to 5 dippers	3 to 5 dippers	3 to 5 dippers
Height of "A" -frame: lowered..	....	15 ft. 0 in.	15 ft. 0 in.	15 ft. 0 in.
Height of "A" -frame: extreme..	14 ft. 6 in.	19 ft. 6 in.	20 ft. 6 in.	21 ft. 8 in.
Wheel base, total (traction).	16 ft. 9 in.	....	....	....
Wheel base, total (truck).	21 ft. 6 in.	31 ft. 0 in.	32 ft. 11 in.	36 ft. 0 in.
Gage of track......	3 ft. 6 in. to 4 ft. 8½ in.[2]	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.
Width over wheels (traction shovel).	11 ft. 6 in.	....	....	....
Fuel, kind..........	Bit. coal	Bit. coal	Bit. coal	Bit. coal
Coal bunker capacity.	4,000 lb.	8,000 lb.	8,800 lb.	8,800 lb.
Car-body, length...	24 ft. 11½ in.	36 ft. 0 in.	38 ft. 0 in.	42 ft. 0 in.
Car-body, width....	7 ft. 0 in.	10 ft. 0 in.	10 ft. 0 in.	10 ft. 0 in.
Water tanks, No....	2	2	2	2
Water tanks, total capacity.	600 gal.	1,950 gal.	2,000 gal.	2,000 gal.
Size of engines: main....	7½×8 in.	10×10 in.	11×11 in.	12×12 in.
Size of engines: swing...	6 ×6 in.	7× 8 in.	8× 8 in.	9× 9 in.
Size of engines: thrust...	6 ×6 in.	7× 8 in.	8× 8 in.	9× 9 in.
Boiler, outside diameter.	58 in.[3]	46 in.	50 in.	52 in.
Boiler, length.......	....	20 ft. 0 in.	20 ft. 0 in.	21 ft. 4 in.
Boiler, height.......	9 ft. 0 in.	....	....	....
Working pressure per square inch.	125 lb.	125 lb.	125 lb.	125 lb.

TABLE XI—Continued

SPECIFICATIONS OF ATLANTIC STEAM SHOVEL

Class	25–11–1–¼[1]	45–16–2–½	60–17–3–½	80–18–4–½
Firebox, length	....	60 in.	66 in.	66 in.
Firebox, diameter inside.	51½ in.	....	....	....
Firebox, width	....	39 in.	44 in.	46 in.
Firebox, height	26. in.	....	....	....
Tubes, number	199	78	88	96
Tubes, diameter	2. in.	2¼ in.	2¼ in.	2¼ in.
Tubes, length	3 ft. 3 in.	11 ft. 6 in.	12 ft. 0 in.	12 ft. 11½ in.
Heating surface, tubes.	338 sq. ft.	528 sq. ft.	621 sq. ft.	753.5 sq. ft.
Heating surface, firebox.	32 sq. ft.	74 sq. ft.	92 sq. ft.	112.2 sq. ft.
Heating surface, total.	370 sq. ft.	602 sq. ft.	713 sq. ft.	865.7 sq. ft.
Grate area	15 sq. ft.	16 sq. ft.	20 sq. ft.	21.2 sq. ft.
Weight in working order.	72,000 lb.	146,000 lb.	164,000 lb.	203,000 lb.
Shipping weights: Car on own wheels.	45,500 lb.	83,900 lb.	93,000 lb.	118,700 lb.
Shipping weights: Boom and attachments.	29,000 lb.	45,300 lb.	57,800 lb.	60,700 lb.
Shipping weights: Total	74,500 lb.	129,200 lb.	150,800 lb.	179,400 lb.

Figure 31 shows the limitations of operation of the Atlantic Steam Shovel, and Figs. 32 and 33 illustrate its use in excavating ore from an iron mine.

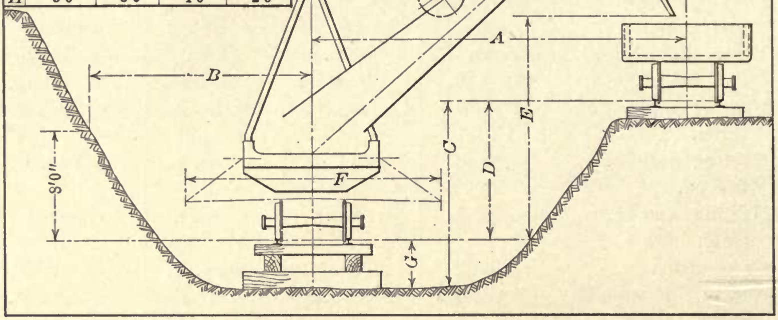
33. Otis Chapman Steam Shovel.—This excavator has been used with success since the early days of railroad construction in this country. It is built by John Souther & Company of Boston, Mass. It is made in sections which can be easily and rapidly taken apart and assembled. Thus it is especially adapted for work in a

[1] The Class 25–11–1–¼ is mounted either upon railroad trucks or upon broad tread traction wheels for use without tracks. When mounted on trucks it is built for track gages of from 3 ft. 6 in. up to 4 ft. 8½ in.

[2] Mounted on railroad trucks.

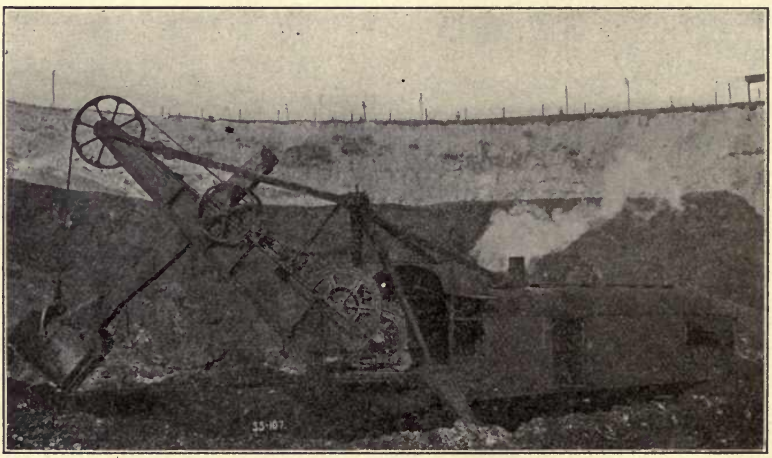
[3] Vertical type.

rough or inaccessible country, where transportation by railroad is not possible. Contractors have found the shovel useful in large contracts where the excavation comprised a large amount of cemented gravel and hardpan.



	Class 80-18-4½	Class 60-17-3½	Class 45-16-2½	Class 25-11-1¼
A	33'0"	30'0"	27'0"	20'0"
B	18'6"	17'6"	16'6"	11'6"
C	11'6"	10'6"	9'6"	4'6"
D	16'6"	15'6"	13'6"	7'0"
E	32'0"	30'0"	26'6"	21'0"
F	19'0"	18'0"	18'0"	13'0"
G	3 to 5 cu. yds.	3½ cu. yds.	2½ cu. yds.	1¼ cu. yds.
H	5'0	5'0"	4'0"	2'6"

Diagram of Limitations of the Atlantic Steam Shovel.
Figure 31.



Atlantic Steam Shovel Stripping Iron Mine.
Figure 32.

The shovel is made in the following sizes:
Railroad mounted standard gage. Length of frame, 30 ft. Weight,

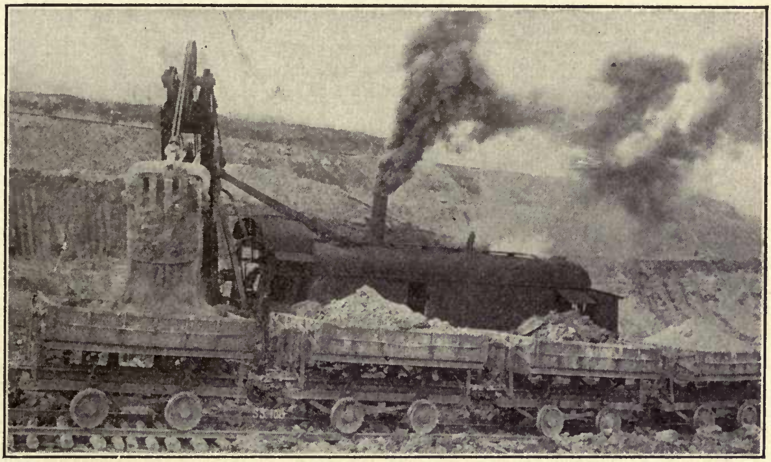
35 tons. Bucket, 2 cu. yd. capacity.

Broad (7 ft. 10 in.) gage. Weight, 25 tons. Bucket, 2 cu. yd. capacity.

Special narrow gage. With broad (7 ft. 10 in.) gage, for working base to steady machine. Weight, 28 tons. Bucket, 2 cu. yd. capacity.

Special railroad mounted. Weight, 45 tons. Bucket, $2\frac{1}{2}$ or 3 cu. yd. capacity.

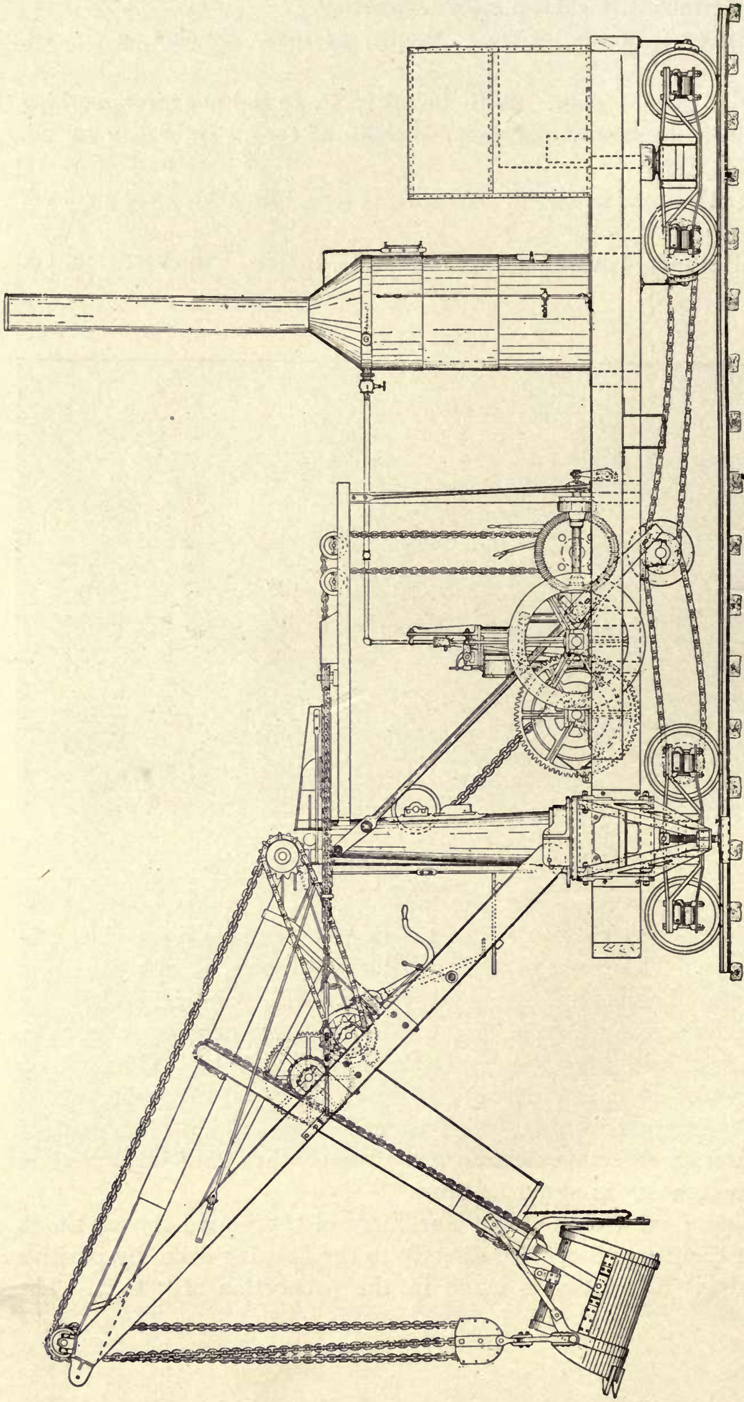
Small standard or special gage. Weight, 20 tons. Bucket, 1 cu. yd. capacity.



Atlantic Steam Shovel loading Dump Cars.
Figure 33.

The special features of construction of this shovel are shown in Fig. 34. The frame is built of heavy timbers, steel plated and strongly braced and bolted together. This combines elasticity with light weight. The usual A-frame is replaced by a circular iron post with the swinging circle pivoted at its top. The pull on the swinging circle is in the plane of the point of application of the load on the crane, which is made very rigid. This feature assures the direct application of the power when swinging and gives it an economy in power and fuel.

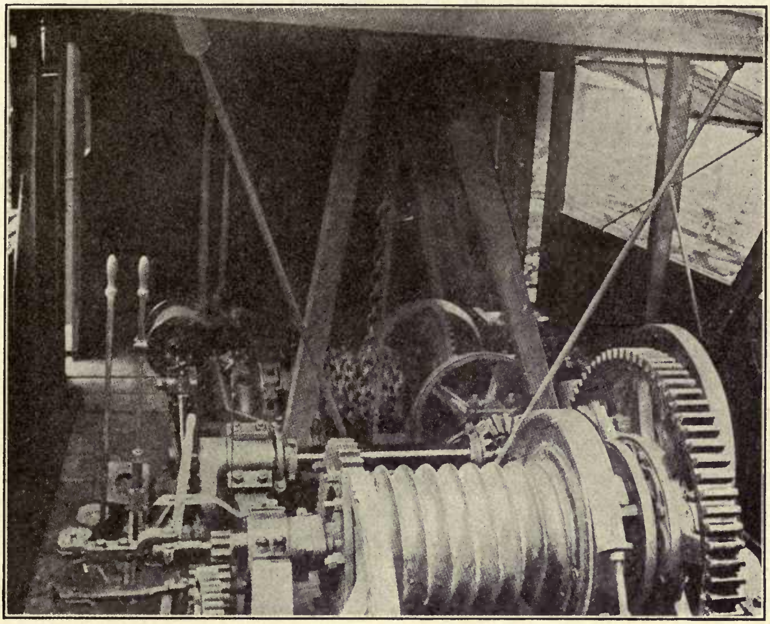
Figure 35, a view of the machinery of the 3-yard shovel, shows that the power is applied directly to the hoisting drum by positive gearing. The latter is made in the proportion of 5 to 1. The



Two-yard Standard Gravel and Hardpan Shovel.
Figure 34.

hoisting gear has a cordial pitch of 2 in. and the swinging gear of $1\frac{1}{2}$ in.

The swinging device has 24-in. cone frictions and can be operated independently of the hoisting drum. By throwing over a small lever, the winch is disconnected from the swinging drum and connected by a gearing to the trucks. The same lever used for the operation of



Machinery of Three-yard Steam Shovel.
Figure 35.

the swinging drum can now be used to move the whole machine backward or forward.

The bucket or dipper is made wide so as to offer a long cutting edge for scraping.

34. **Operation.**—A steam shovel is operated by a crew of seven men, the engineer, cranesman, fireman and four laborers. The engineer and cranesman directly control the movements of the machine. The fireman keeps the boiler supplied with fuel and water and looks after the oiling of the machinery. The laborers are generally under the direct supervision of the cranesman and their duties consist in the breaking down of high banks, assisting the shovel in loading material lodged too near the machine, leveling the surface in front of the

shovel, laying of new track, operating the jack braces and blocking and for general service. When the ground is hard, from two to six extra laborers are required to break down overhanging material in high banks, drill holes and blast out material, assist in loading the shovel, etc.

The engineer stands at the set of levers and brakes placed in front of the machinery, while the cranesman is stationed on a small platform on the right side of the crane near the lower end. The former controls and directs the raising and lowering of the dipper, the swinging of the crane or of the whole machine with a revolving steam shovel, and the traction of the whole machine. The cranesman controls the operation of the dipper and dipper handle regulating the depth of cut, releasing the dipper from the bank and emptying it into the car, wagon or spoil bank.

The act of excavation commences with the dipper handle nearly vertical and the dipper resting on the ground, with the cutting edge directed slightly into the earth. The engineer then moves a lever throwing the hoisting drum into gear and starting the engine. The revolution of the hoisting drum winds up the hoisting line and pulls the dipper upward. At the same time the cranesman starts the engine which controls the thrusting of the dipper handle and moves the latter forward as the dipper rises. These two motions must be made smoothly and coördinately or the hoisting engine will be stopped and the whole machine tipped suddenly forward. When the shovel has reached the top of the cut or its highest practicable position, the engineer throws the hoisting drum out of gear and sets the friction clutch with a foot brake, thus bringing the dipper to a stop. Immediately the cranesman releases his brake and reverses the engine which draws back the dipper handle, thus releasing the dipper from the face of the excavation. When the shovel or dipper digs clear of the excavation, it is unnecessary to release it as described in this last motion. The engineer then starts the swinging drums or engine into operation and swings the boom to the side, until the dipper is over the place for dumping. With a foot brake he sets the friction clutch and stops the revolution of the swinging drum or drums. The cranesman then pulls the latch rope, which opens the latch and allows the door at the bottom of the dipper to drop and release the contents. The engineer then releases the friction clutch by the foot brakes and reverses the swinging engine, pulling the boom and dipper back to its position for the next cut. As the boom is swung around, the engineer gradually releases the friction clutch of the hoisting drum and allows the dipper to drop slowly toward the bottom of the cut. When near

the point of commencing the new cut and as the dipper handle approaches the vertical, the cranesman releases the friction clutch on the engine with his foot brake, which regulates the dipper handle. Thus, as the last part of the drop is made by the dipper, it is also brought into the proper position and the length of the dipper arm set for the deginning of the new cut. As the dipper drops into place, the bottom door closes and latches by its own weight.

The time required to make a cut and dump the excavated material varies from one-half minute for loose earth or gravel to three minutes for hard and dense soils. The length of each complete operation depends to a great extent upon the skill and experience of the operators. The motions described above must be coördinated to produce a smooth and harmonious action. The machinery should always be operated with care, and with the idea of securing regularity rather than speed. Many engineers will tear along at high speed for periods which are, as a result, usually separated by longer shut-downs for repairs. This nervous, spasmodic method of operation is costly and very inefficient and is usually the result of inexperience on the part of the engineer.

After the entire face of the cut has been removed within the reach of the dipper, the machine is moved ahead. When the machine moves on a track, a new section of track is laid ahead of the shovel. The laborers release the jack screws of the braces, and the engineer throws the propelling gear into place, starts the engine and the machine moves ahead 3 or 4 ft. The jack-braces are then set into position, the wheels blocked and the shovel is ready for another series of cuts.[1]

The scope of this book does not permit of a discussion of the system and methods used in various classes of steam-shovel work. The reader is referred to the excellent discussion of this subject in "Steam Shovels and Steam-shovel Work," by E. A. Hermann, and to the "Handbook of Steam-shovel Work," comprising "A Report by the Construction Service Co. to The Bucyrus Company."

35. Cost of Operation.—The cost of operating a steam shovel depends upon the class of work, the kind of material to be excavated, the size and efficiency of the machine, the peculiar conditions affecting each job, the facilities for removing the material, etc.

The cost of operation of a $2\frac{1}{2}$ cu. yd. steam shovel for a 10-hour day, in the excavation of earth and gravel, under average conditions, would be approximately as follows:

[1] See "Handbook of Steam-shovel Work," The Bucyrus Co., Chapter X, for directions for moving shovel.

Labor:		
1 engineer,	$5.00	
1 cranesman,	3.50	
1 fireman,	2.50	
½ watchman @ $50 per month,	1.00	
4 pitmen @ $1.50,	6.00	
1 team and driver (hauling coal, water, etc.),	2.50	
Total labor cost,		$20.50
Fuel and Supplies:		
2½ tons of coal @ $4,	$10.00	
Oil and waste,	1.50	
Water,	.50	
Total fuel and supplies,		$12.00
General:		
Repairs,	$5.00	
Depreciation (5 per cent. of $15,000),	5.00	
Interest (6 per cent. of $15,000),	6.00	
Total general cost,		$16.00
Total cost of operation per 10-hour day,		$48.50
Average excavation,	2,000 cu. yd.	
Average cost of operating shovel, $48.50 ÷ 2000	2.4 cents per cubic yard.	

The same steam shovel used in the excavation of a stiff clay or shale would probably require the services of two extra laborers at $1.50 a day each. The average daily excavation would vary from 800 to 1,200 cu. yd., or with a mean of 1,000 cu. yd., the cost of operating the shovel would be about 5 cents per cubic yard.

For the excavation of rock which requires blasting, the crew for earth excavation would be increased as follows:

4 pitmen, @ $1.50,	$6.00	
2 laborers, @ $1.50,	3.00	
		$9.00
The amount of coal used would be increased by one ton, making an added fuel expense of		$4.00
The following item would be added for blasting:		
Dynamite, powder, caps, fuse, etc.,		$1.50
Total cost of operating shovel per 10-hour day,		$63.00
Average excavation,	800 cu. yd.	
Cost of operating shovel,	8 cents per cubic yard.	

The above statements do not include the cost of transporting the shovel to and from the work, the cost of living and camp expenses, office and other incidental expenses.

The cost of the disposal of the excavated material varies from nothing when the material is directly dumped upon the sides of the excavation, to 15 or 20 cents per cubic yard, when the material must be hauled a long distance and spread. The disposal generally consists of two operations—the hauling and the dumping. The cost of hauling varies with the conveyance used, dump wagon or car, and the length of the haul. On railroad work the cost may sometimes be increased by delays of the trains of dump cars. The cost varies from 3 to 12 cents per cubic yard. The cost of dumping varies from ½ cent per cubic yard for wagons to 1½ cents per cubic yard for cars.

35a. Use in Southern Texas.—An irrigation project in the Rio Grande Valley, Texas, included the construction of a ditch or canal about 21 miles long. This canal had a bottom width of 16 ft., an average of 4½ ft., and side slopes, in earth 2 to 1, in rock 1 to 5, and for embankments 1½ to 1. The grade of the canal was about 6 in. in 1,000 ft. The country through which the canal passes was very rough and necessitated many heavy cuts and fills, a 34-ft. cut in solid rock being made in one place.

The work included the excavation of 90,000 cu. yd. of solid rock, 120,000 cu. yd. of loose rock, and 1,750,000 cu. yd. of earth. Steam shovels of a standard make were used in the entire work.

The daily operating cost of each shovel is given as follows:

1 engineer,	$5.00
1 assistant engineer,	5.00
1 fireman,	2.00
1 coal hauler,	2.00
1 water hauler,	2.00
1 assistant,	2.00
2 tons of coal @ $3.50,	7.00
Total operating cost,	$25.00

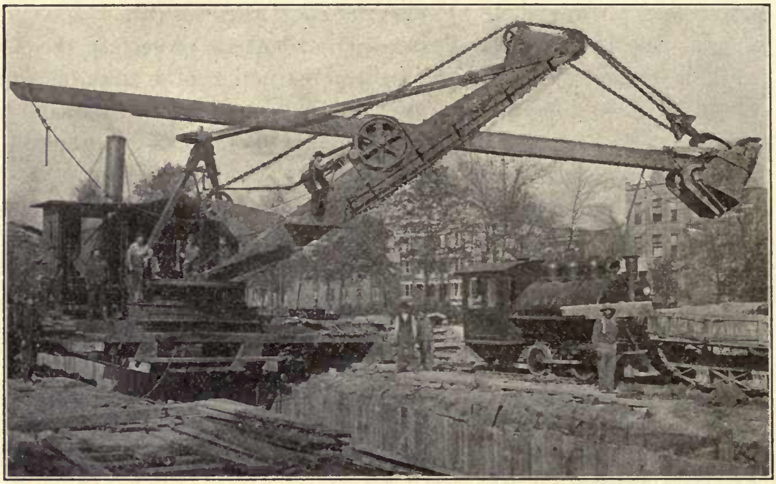
Each shovel excavated on an average of 1,000 cu. yd. of earth or 500 cu. yd. of rock during a 10-hour working day. The size of the dippers used was 1 cu. yd. The total estimated cost of handling the earth was 25 cents per cubic yard and for rock, was 50 cents per cubic yard.

35b. Sewer Trench Excavation in New York.—By the use of a specially rigged boom, called a "trench boom," the revolving type of

shovel may be very efficiently used in the construction of large trenches for sewer and water pipe. During the latter part of the year 1910, in Buffalo, N. Y., a 1-yd. steam shovel having a working weight of 30 tons, excavated 100 lineal feet of sewer trench per day. The trench was 60 in. wide, 15 to 18 ft. in depth, and the material excavated was very hard clay. On this contract, the steam shovel was more efficient than the regular trench excavators, as the former was not delayed by the breakdowns and repairs which the latter required.

At Batavia, N. Y., a $\frac{3}{4}$-yd. dipper, revolving steam shovel excavated 85 lineal feet of sewer trench per day.

Figure 36 shows a Seventy C Bucyrus sewer excavator at work.



Steam Shovel on Sewer Trench Excavation.
Figure 36.

35c. Irrigation Work in Utah.—A self-traction steam shovel weighing about 22 tons and equipped with a $\frac{3}{4}$ cu. yd. dipper is being used (1911–12) in the construction of an irrigation ditch on a project in Grand Valley, near Agate, Utah. The ditch is 10 ft. wide on the bottom, 14 ft. wide on top and $2\frac{1}{2}$ ft. deep in level country. There are several deeper cuts through hills, the maximum depth of which is 10 ft. The shovel was run along the bottom of the ditch on 4-in.×12-in. timbers which served as a track.

The work involves the excavation of 50,000 cu. yd. of shale and 300,000 cu. yd. of sandy loam and clay. Up to the present time (March, 1912) the material excavated has been loose and solid shale.

The crew on the shovel consists of an engineer, a craneman, a fireman, and four laborers. The average excavation has been 200 cu. yd. per day of 10 hours and the average cost of excavation was 16 to 17 cents per cubic yard (not including overhead expenses). In the excavation of loose shale about 1 ton of coal per 10-hour day was consumed and 2 tons in the excavation of solid shale.

The trench was 5 ft. wide and 14 ft. deep and had to be braced. The material excavated was hard blue clay.

35d. Use on Chicago Drainage Canal.[1]—On Section 15 of the Lockport Division, the blasted rock was loaded by two Bucyrus steam shovels of special construction. The dippers were $2\frac{1}{4}$ cu. yd. in capacity and equipped with three teeth each, the two outside teeth being inclined toward the middle tooth.

The table below gives the output of the two shovels for four months.

Month	Number of 10-hour shifts worked	Total cubic yards excavated	Cubic yards excavated per shift
May, 1895..........	108.9	29,000	266
June, 1895..........	99.0	28,850	291
July, 1895..........	96.0	29,000	302
August, 1895........	102.4	31,800	310

The maximum output of one shovel in 10 hours was 600 cu. yd.

On Sections H and G of the Summit Division, a Victor steam shovel, Class No. 1, loaded a hard brick clay into Peteler dump cars of 1 cu. yd. capacity. These cars were hauled by teams. During the months of September, November and December, 1894, the amount of material excavated per 10-hour shift were 662 cu. yd., 920 cu. yd., and $841\frac{1}{2}$ cu. yd., respectively.

On Section F of the Willow Springs Division, Bucyrus steam shovels were used to load the very hard indurated clay, which had been previously blasted. Each shovel loaded two trains of Thatcher dump cars and handled about 350 cu. yd. per 10-hour shift.

On Section E of the Willow Springs Division several small Barnhart's type AA shovels were used to load the very stiff blue and yellow clay, containing large boulders. The material was blasted out ahead of the shovels.

The following table gives the output of these shovels for seven months.

[1] Abstracted from "The Chicago Main Drainage Canal," by C. S. Hill.

Month	Number of 10-hour shifts	Cubic yards excavated per shift
December, 1894	....	403
January, 1895	61	242
May, 1895	59	608½
June, 1895	63	578½
July, 1895	93	562
August, 1895	67	616
September, 1895	67	560

On Section D of the Willow Springs Division, Bucyrus steam shovels loaded glacial drift and rock into dump cars and wagons. The following table gives the records of work done.

Month	Number of 10-hour shifts	Cubic yards excavated per shift
September, 1894	...	1,221
October, 1894	...	743
November, 1894	46	338
December, 1894	...	823(a)
December, 1894	20	504(b)
January, 1895	...	427
May, 1895	113	575
June, 1895	117	517
July, 1895	106	566
August, 1895	117	514
September, 1895	101	472

(a) Loading into cars. (*b*) Loading into wagons.

For every month, except December, the figures given in the above table are the average output of two shovels.

In December, two shovels worked loading cars and one loading wagons. In September, one Bucyrus shovel of the No. 0 Boom type and one "Special Contractor's" shovel were worked. The average of the same shovels per working day per shovel was 1,123 cu. yd.

On Section C of the Willow Springs Division, two steam shovels of the Barnhart Type AA pattern were used in the excavation of the river diversion channel near the old bed of the Desplaines River. The following table gives the output per 10-hour shift for eight months.

Month	Number of 10-hour shifts	Excavation per shovel per 10-hour shift, cubic yards.
August, 1894	....	493
September, 1894	15[1]	820
October, 1894	....	493
November, 1894	73	503
December, 1894	....	538
May, 1895	113	424.5
June, 1895	133	473
July, 1895	124	375

[1] Worked only a few days on account of flooding of channel.

In 1894 two shovels and in 1895 four shovels were used. Two of the four shovels generally loaded into large cars hauled by locomotives and into two small cars hauled up cable inclines. The following table gives an approximate idea of the relative capacities of the two systems.

Shovel	Number of 10-hour shifts	Cubic yards excavated per 10-hour shift
No. 10	16	176(a)
No. 140	22	539(a)
No. 301	36	453(b)
No. 339	39	530(b)

(a) Small cars and incline hoists. (b) Large cars and locomotives.

On Sections B and A of the Willow Springs Division, four Bucyrus special contractors' shovels were used for the handling of the glacial drift. This material consisted of a tough gravelly soil interspersed with a large number of boulders varying from 1 to 10 ft. in diameter. The material was blasted ahead of the shovels.

As on Section C, the shovels loaded into large cars hauled by locomotives and into small cars hauled up inclined conveyors.

In November, 1894, the four shovels worked 97 10-hour shifts and excavated an average of 500 cu. yd. per shift each. In January, 1895, the four shovels worked 103 10-hour shifts and excavated 215 cu. yd. per shift each. The low average for January, 1895, was due

to the very cold weather and frozen soil. The following table gives the record for three months.

Number of shovel	September, 1894		October, 1894		December, 1894	
	Number of shifts	Average cubic yards per shift	Number of shifts	Average cubic yards per shift	Number of shifts	Average cubic yard per shift
172	12	433	3	567	..	....
177	28	630	12	350	28	468
179	29	413	35	514	29	469
181	29	336	50	444	36	492

The following table gives an approximate estimate of the relative capacities of the two systems of loading used.

Number of shovel	Number of 10-hour shifts	Cubic yards excavated per 10-hour shift
177	43	279(a)
184	38	282(a)
179	20½	507(b)
181	25½	482(b)

(a) Small cars and incline hoist. (b) Large cars and locomotive.

On Section 2 of the Lemont Division, two 70-ton Osgood and one 60-ton Bucyrus steam shovels handled the glacial drift, loading into Peteler cars of 3 cu. yd. capacity. The cars were hauled by teams to the foot of cable inclines, thence up the incline by cable and from the top of the incline to the dump by teams.

The two Osgood shovels worked 18 and 24 10-hour shifts in October, 1894, and handled 340 cu. yd. and 395 cu. yd. per shift respectively. On August 2, 1894, one of the shovels excavated the maximum amount of 1,248 cu. yd. (pit measurement) in 10 hours. The same shovel made the largest daily average of 690 cu. yd. for one month. The largest daily average was made from June 6 to Dec. 31, 1894, by this shovel and was 495 cu. yd.

The Bucyrus shovel during October, 1894, worked 23 10-hour shifts and handled 630 cu. yd. per shift. In the month of November,

1894, all three shovels working together averaged 471 cu. yd. per shovel per shift for a total working time of 71 shifts.

The general daily average of the three shovels for the whole working time was 415 cu. yd.

On Section 4 of the Lemont Division, the same methods of excavation and disposal were used as described above for Section 2. Four steam shovels were used, one 70-ton Osgood, one 60-ton Bucyrus, special contractors' type, one 45-ton Bucyrus boom type and one 45-ton Bucyrus crane type.

The Osgood shovel, during October, 1894, worked 27 10-hour shifts and handled 406 cu. yd. per shift. The three Bucyrus shovels worked 27, 24 and 26 shifts and handled 760 cu. yd., 458 cu. yd., and 480 cu. yd., respectively.

During November, 1894, the three shovels worked a total of 103 10-hour shifts and handled an average of 490 cu. yd. per shift each.

The No. 1 boom type, 45-ton Bucyrus shovel made the largest daily excavation of 1,530 cu. yd. (pit measurement), the large monthly average per day of 791 cu. yd. The largest daily average for the season was 594 cu. yd., made by the 60-ton Bucyrus shovel.

On Section 3 of the Lemont Division a Victor steam shovel was used for the handling of the glacial drift. The material was dumped into cars of 3 cu. yd. capacity and hauled in train loads of two cars each. The following table shows the output of the shovel for eight months.

Month	Number of 10-hour shifts	Cubic yards excavated per 10-hour shift
September, 1894	21	362
October, 1894	24	316
November, 1894	18	333
December, 1894	25	392
January, 1895	17	235
May, 1895	22	296
June, 1895	21.6	380
July, 1895	21	330

On Section 5 of the Lemont Division, three steam shovels were used to excavate the glacial drift. These shovels were one Bucyrus Special Contractors', one Bucyrus No. 1 Boom and one Barnhart's AA type. The average output of these shovels for the months of

May, June, and July, 1895, was 354 cu. yd., 440 cu. yd. and 348 cu. yd. per shovel per shift. The excavated material was loaded into dump cars of $1\frac{1}{2}$, 2 and 3 cu. yd. capacity and hauled to the foot of the incline by small locomotives. The cars were then hoisted up the incline by hoisting engines.

The excavation of the dry material of the Chicago Main Drainage Canal was made by steam shovels, working almost continuously. A large part of the material excavated was of a hard, stubborn character and the indurated glacial clay often required blasting before the shovels could handle it. The following general figures give an approximate estimate of the average output of the shovels in different materials.

Stiff clay,	50–70 cu. yd. per hour.
Very hard clay with boulders, blasted,	25–35 cu. yd. per hour.
Medium hard clay with boulders, blasted,	30–40 cu. yd. per hour.
Cemented gravel,	25–50 cu. yd. per hour.
Hard rock, blasted,	25–30 cu. yd. per hour.

The above figures are average results for the steam shovels of 18 years ago, but with the more efficient and powerful shovels of to-day (1913), they should be increased by nearly 100 per cent.

35e. Use of Electric Power Shovel in New York.[1]—The Chautauqua Traction Company of Jamestown, N. Y., for the excavation of ballast has used an electrically operated shovel made by the former Vulcan Steam Shovel Co., of Toledo, Ohio.

This shovel has a car-body 27 ft. long, 6 ft. 8 in. wide, mounted on standard railroad trucks. It is equipped with a $1\frac{1}{2}$ cu. yd. dipper, which has a clear height of lift of 12 ft., will make a cut at level of rails of 26 ft. and will dump at a distance of 4 ft. 6 in., either way from the center of the shovel. The power is furnished by three electric motors; one for hoisting the dipper, one for swinging the boom and one for thrusting the dipper into the bank.

The hoisting motor is 75-h.p. capacity, and is equipped with an automatic magnetic controller, a circuit-breaker and a series overload relay. The circuit-breaker will throw off the current when the motor has attained its maximum safety power and thus prevent overloading. The series overload relay relieves the motor of excess current and prevents burning out. This may be caused by the sudden stopping of the dipper when it strikes an obstruction and the resultant tendency to stall the motor.

The swinging motor is 30 h.p. and is provided with a circuit-breaker,

[1] Abstracted from Engineering-Contracting, Jan. 6, 1909.

an automatic magnetic controller and a solenoid brake. The brake is an electrical device which serves to stop the motion of the crane at the end of its swing. It is provided with a clutch operated by springs, which act as soon as the current is cut off from the motor.

The crowding motor is of 30 h.p. and is provided with an automatic magnetic controller, a circuit-breaker and an overload relay. A foot brake operated by the cranesman furnishes an extra safeguard for the holding of the dipper arm in place.

The following table gives the cost of operation of this shovel per hour.

Labor:		
1 engineer,	$0.33	
1 cranesman,	0.25	
2 pitmen, @ 15 cents,	0.30	
Total cost of labor,		$0.88
Power and Supplies:		
20,346 kw. hours @ 0.0088 cents,	$0.18	
Oil and waste,	0.04	
Total cost of power and supplies,		$0.22
Total cost of operation,		$1.10
Cost of operation per eight-hour day,		$8.80
Amount of excavation per eight-hour day,		534 cu. yd.
Cost of excavation, $8.80 ÷ 534		1.64 cents per cubic yard.

The material excavated was a mixture of gravel, sand and clay. The total working weight of the shovel was about 40 tons.

35f. Use on C. M. & St. P. Ry. near Newcomb, Montana.[1]—The extension of the Chicago, Milwaukee and St. Paul Railway to Seattle on the Pacific Coast was made in many places by the construction of large trestles across valleys. These trestles were later filled in and a permanent embankment made. The Basin Creek bridge required 162,000 cu. yd. of material, which was excavated by a steam shovel in the Newcomb pit and hauled in dump-car trains to the site of the fill.

The following tabulated statement gives a detailed account of this work for the month of March, 1909.

Shovel—Bucyrus No. 453, 2½-yd. dipper, weight of machine 65 tons.
Engines—Prairie type, three in use, tractive power, 33,000 lb.

[1] Abstracted from The Railway and Engineering Review, July 10, 1909.

Cars—Western dump, average load 12.6 cu. yd.
Trains—One engine hauling 13 cars, and a caboose.
Yardage—68,000 cu. yd. handled in 27 working days of 10 hours each.
Yard miles—308,780.
Average haul—4.54 miles. Rate of ascending grade against loads, 88 ft. per mile.

Total Cost, Labor:		
Steam shovel pay-roll,	$1815.64	
Section labor,	99.94	
Total,		$1915.58
Work Train Service, Labor:		
Conductors, 95.8 @ $3.68,	$352.54	
Brakemen, 191.6 @ $2.53,	484.75	
Engineers, 95.8 @ $4.40,	421.52	
Firemen, 95.8 @ $2.95,	282.61	
Total labor,		$1541.42
Fuel and Supplies:		
Supplies, 95.8 days @ $0.32,	$ 30.66	
768 tons of coal @ $4,	3072.00	
1,916,000 gal. of water,	178.83	
Total cost of fuel and supplies,		$3281.49
General:		
Depreciation, 81 days @ $2.03	$164.43	
Interest, 81 days @ 2.03,	164.43	
Repairs, 81 days @ 3.00,	243.00	
Total general cost,		$571.86
Total cost of work train service,		$5394.77
Fuel for Steam Shovel:		
172.8 tons of coal @ $4,	$691.20	$691.20
Camp Maintenance:		
Boarding camp,	$174.27	
Commissary,	15.74	
		$190.01
Total cost of work for March, 1909,		$8191.56
Excavation,	68,000 cu. yd.	
Cost of excavation,	$0.1205 per cubic yard.	

35g. Use in Cleveland, Ohio.[1]—The four-tracking of the Nickel Plate Railway through Cleveland, Ohio, required the excavation of a cut 70 ft. wide, 16½ ft. deep and 600 yd. long. This excavation of about 50,000 cu. yd. was made from May 7, 1909, to August 1, 1909, with 72 working days and an average daily output of 60 carloads of excavated material. The latter was largely hard Cuyahoga shale with a surface soil of earth well mixed with large boulders.

The shovel used was a 75-ton steam shovel of standard make. The level of the original single track was 18 ft. above the grade of the four-track bed and the crane of the shovel had to use a lift of about 20 ft. in order to dump its load into the cars. The crane of shovel had, however, a lift of only 18 ft. 6 in., so that it was necessary to construct a service train track 2 ft. below the grade of the original track.

The cost of excavating and dumping the 50,000 cu. yd. of the main cut is given in the following table.

Steam shovel engineer, 72 days @ $5,	$360.00
Steam shovel craneman, 72 days @ 3,	216.00
Steam shovel fireman, 72 days @ 2,	144.00
Steam shovel watchman, 72 nights @ 2,	144.00
6 laborers, 72 days @ $9,	648.00
Switch engine engineer, 72 days @ $3,	216.00
Switch engine fireman, 72 days @ 2,	144.00
Ploughman for unloadings, 72 days @ $2,	144.00
450 tons of coal @ $1.20 per ton,	540.00
Total cost of main cut,	$2556.00

The excavation of the service train track required 18 days additional time and the estimate of the cost of this work is made on the relative amount of time taken to that for the main cut.

Dirt train track (¼ of $2,496),	$624.00
Steam shovel rent for 90 days @ $15,	1350.00
Repairs, $2.50 per day for 90 days,	225.00
Total cost of work,	$4755.00
Total amount of excavation,	50,000 cu. yd.
Cost of excavation,	$0.0951 per cubic yard

The above does not include the cost of bringing the equipment to and from the work, the depreciation of equipment, interest on investment, office expenses, etc.

35h. Use for Basement Excavation in Chicago, Ill.—A Thew Automatic Revolving steam shovel was used during June and July, 1910,

[1] Abstracted from Engineering-Contracting, August 25, 1909.

for the excavation of a basement for a 12-story building on Michigan Ave., Chicago, Ill. The shovel was of 15 tons weight and equipped with a $\frac{5}{8}$ cu. yd. dipper. The reach of the boom allowed for the excavation of material within a radius of 15 ft. The machine was supported on a truck with four broad-tired wheels.

The excavation was 241 ft. long, 134 ft. wide and 14 ft. deep and the total amount of 17,000 cu. yd. was made within 40 days. The shovel first dug its own pit and then worked across the excavation making continuous parallel cuts. The dipper dumped into wagons of 2 cu. yd. capacity, which passed the machine on a movable runway. A three-horse snatch team was used to help each wagon up the runway.

The labor required to operate the shovel was an engineer, a fireman and two pitmen. The average excavation was 400 cu. yd. for a 10-hour day. The shovel loaded 31 dump wagons in 30 minutes.

35i. Use in Florida.—A 70-ton Bucyrus steam shovel was used during the last eight months of the year 1910 and the first month of 1911 in the stripping of phosphate beds. The work was done during the rainy season and in 11-hour working days of one shift each.

The shovel dumped into 12-yd. Western dump cars which made an average haul of about 1 mile. The average yardage hauled per car was 12.68 cu. yd.

The following table gives a record of the work.

Month, 1910	Number of working days	Number of cars handled	Amount of cubic yards handled
May	11	1,883	23,366.8
June	26	4,327	55,796.2
July	26	3,978	50,479.0
August	27	4,043	47,595.9
September	26	4,726	59,757.9
October	26	3,212	41,899.8
November	26	4,112	54,855.7
December	25	3,411	45,189.4
January, 1911	26	4,381	53,221.3
Total	219	34,073	432,162.0

35j. Use in Georgia.[1]—The Macon Brick Company of Macon, Ga., uses a Vulcan revolving shovel of 25-ton weight for the excavation of

[1] From Engineering-Contracting, April 12, 1911.

the clay for brick manufacture. The company makes from 50,000 to 60,000 bricks per day and uses about 100 cu. yd. of clay.

The Vulcan steam shovel is equipped with a $\frac{3}{4}$-yd. dipper and a dipper handle 12 ft. long. The shovel will dump $12\frac{1}{2}$ ft. above the rail, will clear a floor 32 ft. and make a cut 40 ft. wide in a 6-ft bank.

The following table gives the average daily cost of operation.

Labor:		
1 engineer,	$3.00	
1 fireman,	1.25	
2 trackmen, @ $1.25	2.50	
Total labor cost,		$6.75
Fuel and Supplies:		
600 lb. of coal, @ $3.50 per ton,	$1.05	
Oil, waste and repairs,	0.50	
Total fuel and supplies,		$1.55
General:		
Plant, interest and depreciation,	$1.25	$1.25
Total cost per day,		$9.55
Average daily amount of excavation,	100 cu. yd.	
Average cost of excavation,	$0.0955 per cubic yard.	

35k. Use on Railroad Work in Illinois.[1]—The Burlington System of railroads in 1906 made two improvements in location on the Beardstown-Centralia Division in Illinois. They are known as the Big Shoal cut-off and the Little Shoal cut-off.

The Big Shoal cut-off was a change in alignment and grades between Sorento and Reno, Illinois. The total amount of excavation in the improvement was 318,711 cu. yd., of which 251,711 cu. yd. were steam-shovel work. Two temporary trestles were used, having a total length of 2,961 ft. and an average height of 40 ft. The average haul for the embankment was $1\frac{1}{2}$ miles and the average depth of cut 15 ft. The material handled was a wet clay. The stickiness of the excavated material made its handling difficult and delayed the work to some extent. The trestle was designed to carry a loaded train of 5-yd. dump cars before being filled and the engine in service after being filled. Each bent consisted of two soft wood piles with cap and cross-bracing. For each 13-ft. span, two 8×16-in. stringers were used. The stringers were removed and the remainder of the trestle left in the embankment.

[1] Abstracted from Bulletin No. 81 American Railway and Maintenance of Way Association.

The Little Shoal cut-off was a change in alignment and grades between Ayers and Durley, of Illinois. This work comprised the handling of 188,240 cu. yd. material. This was about 40 per cent. hard pan, which was as hard as the shovel could dig without blasting. A temporary trestle was used, having a total length of 2,142 ft. and an average height of 35 ft. The average haul was ½ mile. On this work the shovel and trains moved over 6 per cent. grades and 16 degree curves without difficulty.

The work was all done by the railroad company and the table below shows the saving made over contract work. This was done in spite of the disadvantages under which the company worked, such as working under the regular schedules and the lack of freedom in the handling of labor, supplies and commissary.

The equipment consisted of a 65-ton Bucyrus steam shovel, two 30-ton switch engines, 43 dump cars of 5 cu. yd. capacity and a Jordan spreader. The shovel worked 228 shifts of 10 hours each, two per day. The average output was 1,104 cu. yd. per shift or 3.35 cu. yd. per car. The labor employed included 70 men during the day shift and 28 during the night shift.

The following table gives a résumé of the cost of the work and the comparative cost by contract.

TABLE XII

COMPARATIVE COST OF COMPANY AND CONTRACT WORK

Character of work	Big Shoal Cut-off		Little Shoal Cut-off	
	Total	Per cubic yard	Total	Per cubic yard
Equipment	$ 2,733	1.0 cents	$ 2,911	1.5 cents
Steam shovel (labor and supplies)	23,351	8.9 cents	18,136	9.6 cents
Temporary trestle	9,008	3.6 cents	5,853	3.1 cents
Track-work	12,438	5.0 cents	7,817	4.2 cents
Engineering and supervision.	610	0.2 cents	487	0.3 cents
Total	$48,140	18.7 cents	$35,204	18.7 cents
Total by contract, at 26 cents per cubic yard.	$65,445	26.0 cents	$48,942	26.0 cents
Saving by company work.	17,305	7.3 cents	13,738	7.3 cents

351. Use in Canal Excavation, Ontario, Canada[1].—The work done was the excavation of a section of the Trent Canal near Trenton, Canada. The average cut was 10½ ft. and was side cutting. The material was gravel and was loaded into cars as high as the machine would reach. The shovel handled 16,000 cu. yd. from June 1 to 12, 1908, the average haul being 1,200 ft. From June 15 to 30, 20,000 cu. yd. were excavated and moved at an average haul of 1400 ft. The total excavation was 36,000 cu. yd. with an average haul of 1,300 ft.

The outfit used consisted of a 65-ton Bucyrus steam shovel with a 2½-yd. dipper, two 12-ton Porter dinkeys, 22 dump cars of 4 cu. yd. capacity and about ⅛ mile of track. The cost of this outfit was approximately as follows:

1 65-ton shovel,	$ 9,000.00
2 12-ton dinkey engines,	5,000.00
22 4-ton dump cars at $230,	5,060.00
16 tons 20-lb. rails @ $32,	512.00
1,000 ties @ 10 cents,	100.00
Total,	$19,672.00

On this investment of $19,672, 2 per cent. was allowed for interest, depreciation and repairs, per month, making a monthly charge of $393.44.

The following statement is based on the fact that 26 days were worked during the month. The shovel worked 12 hours per day and the track gang and water wagon 10 hours per day.

Loading:

1 shovel runner,	$125.00	
1 craneman,	90.00	
1 fireman,	60.00	
4 pitmen,	156.00	
1 team hauling water,	180.00	
50 tons coal @ $5,	250.00	
Oil, waste, etc.,	10.00	
Total,		$ 871.00

Hauling:

2 dinkey runners, @ $3 per day,	$156.00	
2 brakemen, @ $2 per day,	104.00	
1 oiler, @ $1.75 per day,	45.50	
1 trackman, @ $1.50 per day,	39.00	
60 tons coal @ $5,	300.00	
Oil, waste, etc.,	16.00	
Total,		$ 660.50

[1] From Engineering-Contracting, October 14, 1908

Dumping:

1 foreman, @ $3 per day,	$ 78.00	
16 laborers, @ $1.50 per day,	624.00	
1 water boy, @ $1 per day,	76.00	
Total,		$ 728.00

Miscellaneous:

1 superintendent,	$150.00	
1 timekeeper,	65.00	
1 watchman,	40.00	

Track Gang:

1 foreman, @ $3 per day,	$ 78.00	
5 laborers, @ $1.50 per day,	195.00	
Interest, depreciation and repairs,	$390.00	
Total,		$ 918.00
Grand total,		$3177.50

Total amount of excavated material, 36,000 cu. yd.
Cost of excavation, $3177.50 ÷ 36,000 = 8.7 cents per cubic yard.

The cost of excavation may be divided up as follows:

Superintendence,	$0.007
Loading,	0.024
Hauling,	0.018
Dumping,	0.020
Track work,	0.008
Interest, depreciation and repairs,	0.010
Total,	$0.087

35m. Use in Ontario, Canada.—During the year 1886, an Otis-Chapman steam shovel working in its fifteenth season handled 200,943 cu. yd. of gravel on an average haul of 104 miles, at an expense of $7,479. The following table shows the number of cars loaded with gravel by the steam shovel during the season; the cost of hauling the same; the number of miles of track ballasted and its cost and the number of miles of old ballast dug out before putting in the new ballast and the cost of this work.

This work was done on the Michigan Central Railway in Ontario, Canada, and comprised the excavation of the gravel from the Waterford pit and its use in reballasting the tracks.

TABLE XIII

NUMBER CARS LOADED AND COST

Month	Number hours delay and cause				Cost	Remarks
	No. cars	Waiting cars	Rain	Rep'g shovel		
April 19 to 30....	1,300	$5\frac{1}{2}$	$4\frac{1}{2}$	6	$ 435.50	Average number yards per car, 9.
May 1 to 31......	3,142	8	......	$9\frac{1}{2}$	1,052.57	
June 1 to 30......	3,111	2	......	....	1,042.18	Height of bank, 8 to 12 ft.
July 1 to 31......	3,167	$1\frac{1}{2}$	......	17	1,060.94	
August 1 to 31...	3,030	$8\frac{1}{2}$	......	$1\frac{1}{2}$	1,015.05	
September 1 to 30	2,920	$10\frac{1}{2}$	1	17	978.20	Cost includes coal, oil, waste, repairs, labor, and engine service.
October 1 to 31...	3,056	$1\frac{1}{2}$	......	....	1,023.76	
November 1 to 30.	2,601	$2\frac{1}{2}$	......	$2\frac{1}{2}$	871.33	Average haul, 104 miles.
	22,327	40	$5\frac{1}{2}$	$53\frac{1}{2}$	$7479.53	

Average cost per car, $0.33\frac{1}{2}$ cents, delivered road bed.
Average cost per yard, $0.03\frac{13}{18}$ cents, delivered road bed.
Average cost per car, $0.14\frac{1}{4}$ cents, steam-shovel service only.
Average cost per yard, $0.01\frac{7}{10}$ cents, steam-shovel service only.

35n. Use in Missouri.—The following report has recently (May, 1912) been made by the Superintendent of Mines of the American Zinc, Lead and Smelting Company of Cartersville, Missouri, on the use of a Thew Automatic steam shovel in their mines.

"There have been no breaks in any part of the machine during the three months it has run; even though it has been subjected to very trying conditions. The repairs are very light. Of course, the dipper teeth wear rapidly, necessitating a new set about once a month. The dipper will last about 6 months.

"Owing to the low face, averaging from 12 to 15 ft., it is necessary for the shovel to move frequently to get its rock. The bottom is practically level, the ore-body being a bedded deposit. Pillars, averaging 25 ft. in diameter, are left about every 40 ft. The face is approximately a circle around which the shovel moves, clearing up the broken rock as it goes. The material handled is extremely hard, being practically nothing but flint.

TABLE XIV

COSTS OF STEAM-SHOVEL WORK

Item	January		February		March	
	2,778 tons		3,238 tons		3,950 tons	
	Total	Cost per ton	Total	Cost per ton	Total	Cost per ton
Shovel men........	$127.63	$0.0459	$159.68	$0.0493	$230.47	$0.0583
Conveying to shaft..	184.72	0.0665	168.68	0.0521	91.86	0.0233
Compressed air.....	45.81	0.0161	62.86	0.0191	71.07	0.0180
Oil and gasoline....	5.71	0.0020	7.89	0.0024	7.35	0.0018
Repairs............	10.98	0.0040	27.78	0.0086	16.60	0.0042
Total............	$374.85	$0.1345	$426.89	$0.1315	$417.35	$0.1056

"The rock is conveyed from the shovel to the shaft, a distance of 400 ft. in a can or tub, running on a small car. Each can holds 1,500 lb. Four or five of these cars are coupled together, and pulled to the shaft by a mule. The conveying from the face to the shaft requires four men. One mule driver, two car couplers, and a man to run the empty can up to the shovel and the full can to the coupler. The wages paid these men are as follows:

Shovel operator,	$ 3.00
Shovel helper,	2.00
Mule driver,	2.25
Runner,	2.00
Two car couplers,	3.00
Total,	$12.25

"The power cost is slight, the machine running on compressed air, and consuming practically 25 h.p. The table herewith gives the detailed costs per ton.

"The reduced cost for March was due, mainly to putting in a mule to haul the cars; previous to this they were run by men. The cost per ton by contract or hand shoveling for March was $0.1111. The results obtained here show that the automatic shovel is adapted for underground work, and would show up much better if working under more favorable conditions."

35-0. Use in North Dakota.—The Red River Valley Brick Company of Grand Forks, North Dakota, make the following report on the use of a No. 0 Thew Steam Shovel for the excavation of clay in their brickyard for the seasons of 1909, 1910 and 1911.

TABLE XV

COST OF OPERATING No. 0 THEW STEAM SHOVEL FOR THREE SEASONS

Cost per working day for season	1909	1910	1911	Average
Wages of engineer	$2.69	$3.45	$ 3.66	$3.26
Wages of fireman	2.11	2.00	2.16	2.09
Wages one laborer	1.68	2.00	2.18	1.96
Oil and waste	0.12	0.08	0.08	0.09
Coal at $5.65 per ton	1.53	1.81	1.65	1.67
Water	0.08	0.10	0.08	0.09
Repair	....	0.33	0.54	0.29
Total cost	$8.21	$9.77	$10.35	$9.45
Pounds coal consumed daily	565	643	597	602
Gallons water consumed daily	486	639	489	538
Cubic yards clay used daily	197	320	273	264
Number brick made daily	90,000	144,000	124,000	120,000
Cost loading clay per thousand	$0.09	$0.07	$0.084	$0.082
Cost loading clay per yard	$0.04	$0.03	$0.038	$0.036
Cost shovel repairs per yard	none	$0.0009	$0.0019	$0.0009

"If we were only making 60,000 brick per day the fireman could be dispensed with, but the shovel supplies clay for three machines, averaging 48,000 per day for each machine and the clay bank being only 4 to 5 ft. deep it requires the three men but not hard work for any of them.

"Our coal is weighed every day by the steam-shovel fireman and the daily record is on file in our office. The water is measured by individual meter so that this item is absolutely correct.

"The cost of putting clay on the cars at a yard where we did not have a shovel was 9 cents per cubic yard."

35p. Use on Panama Canal.—The following notes of steam-shovel work have been taken from the Canal Record and several engineering periodicals.

Records for April, 1908, in four construction districts of the Culebra Division are given in table, on Page 88.

Shovels in the "100" class are 70-ton shovels with buckets of 2½ cu. yd. capacity. Shovels in the "200" class are 95-ton shovels with dippers of 5 cu. yd. The shovels operate during an eight-hour day.

Shovel number	Location	Excavated material, cubic yards	Kind of material
216	Empire	2,780	Rock and earth
124	Empire	1,608	Rock
215	Bas Obispo	2,904	Earth
127	Bas Obispo	2,076	Rock and earth
202	Pedro Miguel	2,600	Earth
123	Pedro Miguel	1,469	Earth
222	Culebra	2,612	Rock and earth
152	Culebra	1,704	Rock and earth

On March 2, 1909, shovel No. 220 removed 3,941 cu. yd. of earth and rock in an eight-hour working day. The shovel was actually operating during six hours and fifty minutes, the remaining period of one hour and ten minutes being spent in waiting for cars.

During June, 1909, the following records were made:

Shovel No. 204, working in the Culebra District excavated 49,767 cu. yd. of earth in 25 working days or an average of 1,990.7 cu. yd. per day.

Shovel No. 132, working in the Tabernilla District, excavated 30,021 cu. yd. of earth in 25 working days or an average of 1,200.8 cu. yd. per day.

Shovel No. 223, working in the Culebra District, excavated 3,268 cu. yd. of rock on June 24.

Shovel No. 132, working in the Tabernilla District, excavated 2,060 cu. yd. of earth on June 26.

During August, 1909, the following records were made:

Shovel No. 223, working in the Culebra District, excavated 45,694 cu. yd. of earth in 26 working days, or an average of 1,757.5 cu. yd. per day.

Shovel No. 204, working eight days in the Culebra District, excavated 16,755 cu. yd. of earth or an average of 2,094.4 cu. yd. per day; working 18 days in the Empire District, excavated 26,518 cu. yd. of earth, or an average of 1,473.2 cu. yd. per day.

Shovel No. 217, working in the Culebra District, excavated 2,549 cu. yd. of earth and rock on August 31.

Shovel No. 108, working in the Bas Obispo District, excavated 31,299 cu. yd. of earth in 26 working days, or an average of 1,203.8 cu. yd. per day.

Shovel No. 127, working in the Tabernilla District, excavated 1,750 cu. yd. of earth on August 14.

During May, 1910, the following records were made:

Shovel number	District	Excavation earth	Excavation rock	Total excavation	Working days
127	Chagres............	34,894	....	34,894	25
114	Chagres............	31,303	....	31,303	24
211	Empire............	....	44,500	44,500	25
210	Empire............	....	37,144	37,144	25
224	Culebra...........	....	41,672	41,672	25
208	Culebra...........	....	40,539	40,539	24

The following daily records were made during May, 1910.

Shovel number	District	Date	Character of excavated material	Excavation cu. yd.
111	Chagres.........	May 6......	Earth.............	1,500
209	Chagres.........	May 3......	Earth.............	1,490
111	Chagres.........	May 7......	Earth.............	1,450
211	Empire.........	May 12.....	Rock.............	2,432
211	Empire.........	May 11.....	Rock.............	2,391
210	Empire.........	May 23.....	Rock.............	2,165
217	Culebra.........	May 5......	Rock and earth....	3,477
217	Culebra.........	May 6......	Rock and earth....	3,249
208	Culebra.........	May 23.....	Rock.............	3,059
231	Pedro Miguel....	May 26.....	Rock.............	2,850

The monthly records were based on place measurement and the daily records on car measurement.

The following table gives the record of excavation made by several 70-ton shovels during eight months of 1910 on the relocation of the Panama railroad. This record is remarkably good considering that the work was done during a very rainy season.

Month, 1910	Output cu. yd.	Average number of shovels	Number of working days	Output per shovel	
				Per day cu. yd.	Per month cu. yd.
January.........	206,334	8.24	25	1,002	25,040
February........	214,411	7.91	23	1,179	27,106
March...........	234,571	7.31	26	1,234	32,089
April............	212,097	7.15	26	1,140	29,648
May.............	212,135	7.88	25	1,077	26,921
June.............	236,689	8.00	26	1,138	29,586
July.............	197,069	7.44	25	1,060	26,488
August..........	250,341	7.04	27	1,318	35,575

The following record of excavation was made during January, 1910.

Shovel No. 223, working in the Culebra District, excavated 50,933 cu. yd. of rock, in 25 working days, or an average of 2,037.3 cu. yd. per day.

Shovel No. 219, working in the Culebra District, excavated 50,270 cu. yd. of rock in 25 working days or an average of 2,010.8 cu. yd. per day.

Shovel No. 111, working in the Bas Obispo District, excavated 27,688 cu. yd. of earth in 23 working days, or an average of 1203.8 cu. yd. per day.

Shovel No. 218, working in the Empire District, excavated 3,009 cu. yd. of rock on January 8.

The steam shovel No. 213, working in the Culebra District, on March 22, 1910, excavated 4,823 cu. yd. of earth and rock, place measurement. The material was loaded on 235 Lidgerwood cars and the division of time was as follows:

Time loading cars,	320 minutes
Moving up 20 times @ 5 minutes,	100 minutes
Waiting for cars,	55 minutes
Coaling shovel,	5 minutes
Total time,	480 minutes or 8 hours.

The expense for labor and supplies is given below.

Labor:

1 engineer, 1 day @ \$7.56,	\$7.56	
1 craneman, 1 day @ \$6.48,	6.48	
1 foreman, 1 day @ \$2.83,	2.83	
2 firemen, 1 day @ \$1.67,	3.34	
1 laborer, 8 hours @ \$0.13,	1.04	
7 laborers, 8 hours @ \$0.16,	8.96	
Total labor,		\$30.21

Supplies:

$5\frac{1}{4}$ tons of coal @ \$4.41,	\$23.15	
3 gal. of car oil @ \$0.18,	0.54	
2 gal. of valve oil @ \$0.31,	0.62	
2 lb. of cup grease @ \$0.10,	0.20	
1 lb. of gear grease @ \$0.08	0.08	
Total supplies,		\$24.59
Grand total,		\$54.80
Total excavation,	4,832 cu. yd.	
Cost of excavation; \$54.80÷4,832=	\$0.0114 per cubic yard.	

35r. Use in South Dakota.—The construction of the large earthen dam to form the reservoir of the Belle Fourche Project of the Reclamation Service involved the excavation of a large amount of gravel and clay and its transportation to the site.

The dam was built across the valley of Owl Creek near Belle Fourche, South Dakota. It has a length of about 4,000 ft. at the top; the width at bottom, near the center, was about 200 ft., height at center about 90 ft. and top width of 20 ft. A steam shovel was used to excavate the material from a hill near each end of the dam. The excavated material was hauled in trains of dump cars upon the site, dumped, spread out with scrapers into layers from 6 to 9 in. deep, sprinkled and then rolled with steam rollers. The layers were not carried clear through the width of the dam, but were made in varying widths and thicknesses so as to break joints.

Mr. F. C. Magruder, Project Engineer, has kindly furnished the following information as to the methods and costs of this work.

Two 75-ton Vulcan steam shovels with $2\frac{1}{2}$ cu. yd. dippers were used during the season of 1908, loading trains made up of 4 cu. yd. side dump cars hauled by 18-ton Davenport dinkeys. At the begin-

ning of the season one shovel was moved from pit at north end of dam to a pit at south end, a distance of 7,500 ft. and at the end of season was moved back to North Pit again. The cost of moving shovel, dinkeys and cars, amounting to $1,290 or 1 cent per cubic yard excavated, has been charged in the South Side Shovel costs.

North Side shovel had an average cut of 22 ft. and haul of 4,800 ft., using four 10-car trains for hauling. South Side shovel had an average cut of 6.5 ft., haul of 3,700 ft. and used three eight-car trains. On account of shallow pit, South Side shovel made 15 cuts during the season, while North Side shovel made only four cuts. Cost of moving shovel back in pit was $0.011 per cu. yd. and $0.002 per cu. yd. respectively.

Switches were placed more advantageously in North Pit than in South Pit, causing a minimum amount of lost time in the former waiting for trains to pass.

Spreading was done by four-horse fresno scrapers hauling the dirt about 50 ft. each way from the track, and after watering with 2-in. hose, was leveled by four-horse road leveler and rolled with a 21-ton traction engine. Track was shifted 13 ft. every third layer.

The labor cost includes all cost of superintendence, office expenses, telegraph and telephone bills and other general expenses. Wages for common labor were $1.75 per day, working 10 hours until October 26 and 8 hours for the balance of the season.

The repair charge is made up of the cost of all repair parts as taken from Hayes Bros. invoices, together with the labor cost of putting in those repairs.

Depreciation charges are based on amount of work to be done by each piece of machinery, and estimated salvage at the end of the job.

Supplies include coal, oil, waste, boiler compound, packing, hose, powder, etc. Coal costs, delivered on the job, from $7.50 to $10.50 per ton.

TABLE XVI
CONSTRUCTION COSTS OF LARGE EARTHEN DAM

Item	South side shovel		North side shovel		Total	
	Yardage, 126,885 cu. yd. Daily average, 824 cu. yd.		Yardage, 185,005 cu. yd. Daily average, 1,258 cu. yd.		Yardage, 311,940 cu. yd. Daily average, 1,036 cu. yd.	
	Total cost	Cost per cu. yd.	Total cost	Cost per cu. yd.	Total cost	Cost per cu. yd.
Excavation:						
Labor	$6,669.04	$0.0526	$6,001.63	$0.0324	$12,670.67	$0.0406
Depreciation	3,056.32	0.0241	3,367.71	0.0182	6,424.03	0.0205
Repairs	1,890.00	0.0125	1,815.81	0.0098	3,405.81	0.0110
Supplies	4,548.98	0.0358	4,979.17	0.0269	9,526.10	0.0306
Total	15,862.50	0.1250	16,164.32	0.0873	32,026.66	0.1027
Hauling:						
Labor	2,868.19	0.0226	4,077.33	0.0220	6,945.52	0.0222
Depreciation	2,854.31	0.0225	4,404.81	0.0238	7,259.12	0.0233
Repairs	1,974.00	0.0156	2,438.57	0.0132	4,412.57	0.0141
Supplies	5,232.32	0.0413	7,178.44	0.0388	12,410.76	0.0398
Total	12,928.82	0.1020	18,099.15	0.0978	31,027.97	0.0994
Main track:						
Labor	328.48	0.0026	888.49	0.0048	1,216.97	0.0039
Depreciation	164.30	0.0013	448.90	0.0024	613.20	0.0020
Repairs	76.00	0.0006	75.00	0.0004	150.00	0.0005
Total	567.78	0.0045	1,412.39	0.0076	1,980.17	0.0064
Temporary track:						
Labor	2,486.09	0.0196	3,017.41	0.0163	5,503.60	0.0176
Depreciation	430.57	0.0034	746.50	0.0040	1,177.07	0.0038
Repairs	125.00	0.0010	225.00	0.0012	350.00	0.0011
Total	3,041.66	0.0240	3,988.91	0.0215	7,030.67	0.0225
Spreading:						
Labor	7,117.25	0.0561	10,068.46	0.0543	17,185.71	0.0552
Depreciation	42.25	0.0003	67.13	0.0004	109.38	0.0003
Repairs	3.00	0.0000	3.00	0.0000	6.00	0.0000
Total	7,162.50	0.0564	10,138.59	0.0547	17,301.19	0.0555
Rolling:						
Labor	880.60	0.0069	1,121.11	0.0061	2,001.71	0.0064
Depreciation	408.40	0.0032	562.60	0.0031	991.00	0.0032
Repairs	1,245.00	0.0098	1,562.31	0.0084	2,807.31	0.0090
Supplies	1,247.34	0.0099	1,854.86	0.0100	3,093.20	0.0099
Total	3,781.34	0.0298	5,111.88	0.0276	8,893.22	0.0285
Watering:						
Labor	1,114.91	0.0088	1,400.51	0.0075	2,515.42	0.0081
Depreciation	656.05	0.0052	967.83	0.0052	1,623.88	0.0052
Repairs	124.00	0.0010	182.88	0.0010	308.88	0.0010
Supplies	788.17	0.0061	1,057.03	0.0057	1,845.20	0.0058
Total	2,683.13	0.0211	3,608.25	0.0194	6,291.38	0.0101
Total:						
Labor	21,464.56	0.1692	26,574.91	0.1434	48,039.50	0.1540
Depreciation	7,612.20	0.0600	10,585.48	0.0571	18,197.68	0.0583
Repairs	5,136.00	0.0405	6,302.57	0.0340	12,438.57	0.0367
Supplies	11,814.81	0.0931	15,060.50	0.0814	26,875.31	0.0861
Total	46,027.57	0.3628	58,523.49	0.3159	104,551.06	0.3351

35s. Use in Maine.[1]—An Otis-Chapman shovel has recently (1910–12) been used for the excavation of earth to supply material for the embankments which form the southerly and northerly ends of the Aziscohos storage dam near Colebrook, New Hampshire.

The shovel borrow pit was located on a hillside about 500 ft. from the site of the embankment, and the slope to the embankment permitted gravity transportation, by carts, of the excavated material. The shovel worked most efficiently with a heading face of from 6 to 10 ft.

The material was very compact and hard to work, being a glacial deposit of a clayey nature, locally called rock flour, with about 5 to 6 per cent. of large boulders and a low percentage of small stone.

The total amount of earth excavated by the shovel was 23,614 cu. yd. A little over 5,000 cu. yd. were placed by hand with derricks and skips, double shoveling at a cost of $1.15 per cubic yard, including superintendence and overhead charges.

The following is a statement of the cost per cubic yard of the various portions of the work.

Shovel and pitmen,	$0.115 per cubic yard.
Dumpmen and puddlers,	0.105 per cubic yard.
Hauling (cars),	0.039 per cubic yard.
Grubbing and clearing pit,	0.030 per cubic yard.
Move shovel and repair shovel,	0.022 per cubic yard.
Move railroad tracks and repair cars,	0.027 per cubic yard.
Total,	0.338 per cubic yard.
Supt., insurance, general and overhead charges.	0.081 per cubic yard.
Total labor,	0.419 per cubic yard.
Fuel (wood),	0.014 per cubic yard.
Plant,[2]	0.206 per cubic yard.
Total cost of bank,	$0.639 per cubic yard.

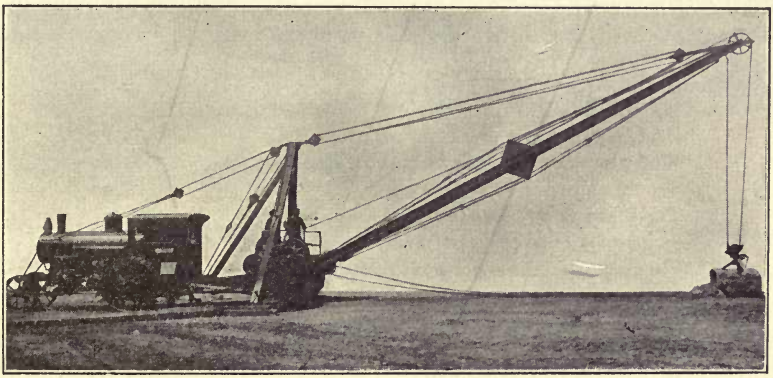
The best day's run was 408 cu. yd. in 11 hours on Sept. 17, 1912. The detail costs for that day were:

[1] From report of Seth A. Moulton, Portland, Maine.

[2] Plant charge would have been much less with larger quantity to move.

	Total	Unit
Steam-shovel men,	$11.25	$0.0275
Pitmen,	15.95	0.0391
Man splitting fuel for shovel,	2.20	0.0054
Dumpmen and spreaders,	18.55	0.0454
Hauling,	11.80	0.0289
Grubbing and clearing pit,	6.60	0.0162
Repairing cars and track,	2.50	0.0061
Total,	$68.85	0.1686
Supt., general and overhead charges 24 per cent. (average),		0.0404
Total labor charge,		0.2090
Fuel,	3.40	0.0083
Total without plant,		$0.2173

36. Avery Traction Shovel Outfit.—A form of steam shovel outfit, which has been used in the Middle West in the construction of drain-



Avery Traction Steam Shovel.
Figure 37.

age ditches is the Avery traction steam shovel and crane. Fig. 37 gives a general view of this machine.

The outfit consists of a locomotive type of undermounted traction engine, and a shovel framework. The latter consists of a steel frame carried on two wheels, 36 in. in diameter, 20-in. face and enclosed sides. Supported on the main frame is an upright A-frame, built of steel channels. The whole framework is well braced with steel struts and bars. Supported on the lower or main frame is the upper

frame carrying the boom and machinery. The upper frame revolves on the lower or fixed frame by means of a large gear and a small pinion. A dipper having a capacity of $\frac{3}{4}$ cu. yd. or 1 cu. yd. is suspended from the end of the boom. The shovel and boom are operated by a pair of drums in the center of the upper, revolving frame. The power for the hoisting and swinging of the boom and shovel is furnished by steam carried through a pipe from the traction engine.

This outfit does not require a track to run on and the shovel framework can be easily dismantled and the outfit moved from place to place.

36a. Use in South Dakota.—One of these steam-shovel outfits with a 32-h.p. engine and $\frac{3}{4}$-yd. shovel was used during the years 1910 and 1911, in the construction of several miles of lateral ditches to the Clay Creek Ditch in Clay County, South Dakota. The ditches had a depth varying from $3\frac{1}{2}$ ft. to 8 ft., bottom width of 3 ft., and a side slope on one side of 1 to 1 and on the other side the excavated material was wasted so as to form a road embankment. The material excavated was a stiff clay and loam and in sections a hard gumbo. The following report of the construction work is compiled from an estimate made by the operator of the shovel and the owner, who was the contractor.

Average Daily Expense of Operating Outfit

(Average day of 11 hours)

Coal, 1,500 lb. per day at $7 per ton,	$5.25
Water hauler using four tanks of water daily,	4.00
Shovel runner at $100 per month,	4.00
Trackman at 20 cents per hour,	2.00
Swingman at 20 cents per hour,	2.00
Fireman at 20 cents per hour,	2.00
Cook at $30 per month,	1.20
Board for six people at $10 per week,	1.65
Oil per day,	1.00
Repairs per day, estimated,	1.00
Depreciation per day based on 10-year life,	4.25
Interest per day based on 10-year life and 150 working days per year,	2.60
Total,	$30.95

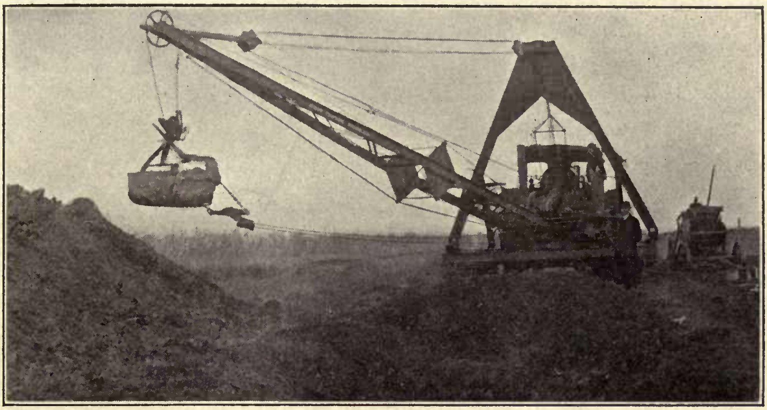
The average daily excavation was 500 cu. yd. making the cost of the work 6.19 cents per cubic yard. The contract price for the entire work was $11\frac{1}{2}$ cents per cubic yard.

36b. Use in Illinois.[1]—Recently in Illinois one of these machines excavated in blue clay a ditch having a bottom width of 6 ft., an

[1] From Engineering News, April 6, 1911.

average depth of 6½ ft. and an average top width of about 20 ft. A 30-h.p. traction engine furnished the power for the operation of a 1-yd. bucket. An average daily progress of 150 ft. was made during a month's continuous work, while a maximum day's progress of 400 ft. was reached. On levee work, this machine handled 1½ to 2 cu. yd. per minute, in excavating heavy gumbo soil.

Figure 38 shows an Avery steam shovel constructing a typical drainage ditch in Missouri.



Avery Traction Shovel Excavating a Drainage Ditch.
Figure 38.

37. Résumé.—The steam shovel is one of the most efficient and universally useful of modern excavators. When the soil is sufficiently firm to support it and the work is of sufficient magnitude to warrant its use, it can be used economically for all classes of work, such as railroad cuts, the excavation of streets, trenches, ditches, cellars, the stripping of ore beds, gravel pits and clay beds, etc., etc. It can be used for the excavation of all kinds of material from loam and clay to hard-pan and rock. Rock in formation must be loosened by blasting before the shovel can handle it.

The output of a steam shovel depends on its size, the character of the material to be excavated, the efficiency of the crew, climatic conditions, location of material with relation to the shovel, relation of shovel to point of dumping, efficiency of wagon or car service, etc. When working under favorable conditions, the maximum working capacity of a shovel will average about one-half of its theoretical efficiency. It is almost impossible to keep a shovel continuously supplied with

wagons or cars and even so, this would mean perfect operation without delays for repairs, breaks, coaling, watering, oiling, etc.

The cost of operation and capacity of a steam shovel, as stated in the previous paragraph, depend on a great many factors, and it is difficult to arrive at any stated values. Recent results from the use of steam shovels on the Panama Canal indicate the following:

A 70-ton shovel, equipped with a $2\frac{1}{2}$-cu. yd. dipper will average 1,200 cu. yd. of earth excavation during an eight-hour working day.

A 95-ton shovel, equipped with a 5-cu. yd. dipper will average 2,500 cu. yd. of earth and rock excavation and 2,000 cu. yd. of rock, during an eight-hour working day.

Fow the making of estimates, the author would suggest adding the following to the estimated cost of operation:

Ten per cent. on initial cost of plant for depreciation,
Six per cent. on initial cost of plant for interest on investment,
Five per cent. on initial cost of plant for repairs.

The small, revolving type of shovel has demonstrated its efficiency for ordinary jobs such as small railroad cuts, street grading, cellar excavation and for use in the clay pits of brickyards and cement works. The electrically operated shovel is the most economical for electric traction work and in large cities where the current is accessible at a low unit cost.

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PART II

DREDGES

DREDGES

Introductory.—As has been pointed out in the preceding Article, the steam shovel is not well adapted to the excavation of ditches or canals in wet lands, where the supporting power of the soil is small. The base of the steam shovel is long and narrow and thereby concentrates the heavy load of the shovel and loaded dipper over a small area.

The crane or boom of the steam shovel is made short and of heavy construction so as to exert a great pressure within a small space. With the demand for an excavator with a long boom for the removal of the material to spoil banks distant from the excavation, and also for a wide base over which to distribute the load as a small unit pressure over soft soil, the dredge or dredging machine was devised. This term may be applied to any type of power excavator, except the steam shovel used for the construction of an open ditch or canal.

Dredges may be divided in two general classes, dry-land excavators and floating excavators.

CHAPTER VI

DRY-LAND EXCAVATORS

40. Classification.—The dredges of this class, as may be understood from the name, are those which move over the surface of the land. They may be classified as to the type of construction and the method of excavating the material, as follows: A, Scraper Excavators; B, templet excavators; C, wheel excavators; D, walking excavators, and E, tower excavators.

A.—SCRAPER EXCAVATORS

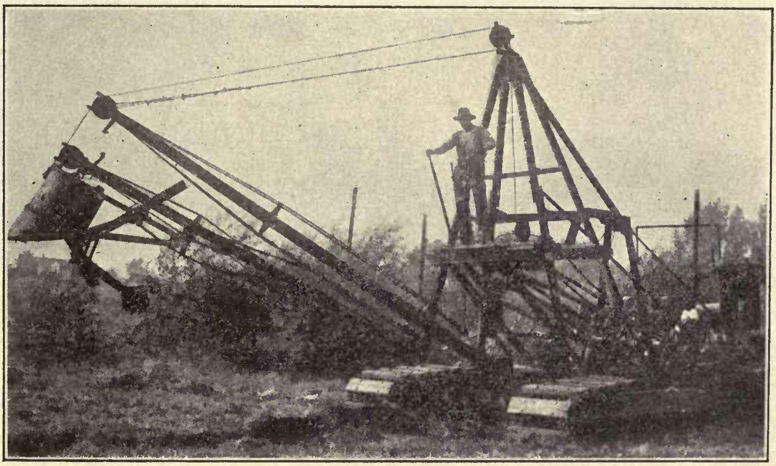
41. Varieties.—Scraper excavators or dredges may be classified as to their method of operation and propulsion. Considering method of operation, there are (1), the rotary or revolving dredge and (2), the stationary dredge with pivoted boom. As regards method of propulsion, there are (1) the drag boat dredge, and (2) the traction dredge. The drag boat is the application of a floating dipper dredge to dry-land work by constructing a narrow and deep hull, which may be drawn along the excavated ditch by means of cables anchored ahead of the boat. As this type of boat is very limited in its scope, rarely used at the present time and properly a dipper dredge, no further description will be given of it here.

42. Traction Excavator with Two Booms.—The earliest type of scraper dredge comprised a framework which carried the boiler, engines, coal bunkers, A-frame, boom, dipper or scraper and various sheaves, piping, etc. The whole machine, platform or framework and superimposed load, moves along ahead of the work on rollers. A machine of this type has been used in the excavation of large ditches in Iowa and Minnesota.

The principal feature of this excavator is the use of two booms, set a distance apart depending on the width of the ditch to be excavated. The booms swing from the center of the ditch to each side. The buckets are fastened to arms which slide along the booms. Each bucket is filled by lowering the point of the boom and moving the bucket through the earth toward the machine. The bucket is

emptied by raising the point of the boom and swinging to the side of the ditch. One bucket is filled while the other is dumped. The excavator was used in the construction of ditches with bottom widths varying from 3 to 25 ft. and made a very uniform cross-section with smooth side slopes and fairly true grade. On account of the excessive weight of such a large machine and the difficulty and expense of moving it over soft, marshy land and uneven, broken country, this type of excavator has been generally superseded by the revolving type of scraper bucket machine.

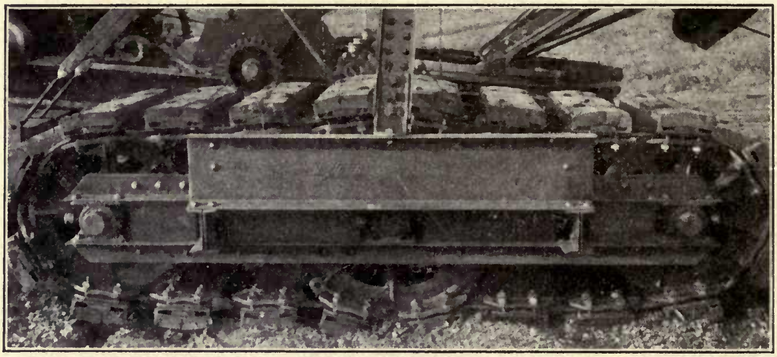
43. **Gopher Ditching Machine.**—Recently, however, a modification of the original scraper bucket and swinging boom excavator has come into use for the construction of small ditches. This machine is shown in Fig. 39 and is called the "Gopher Traction Dry-land Ditching Machine," manufactured by the Dix Machine Co., of Stillwater, Minn.



Gopher Dry-land Traction Ditcher.
Figure 39.

As will be seen from the illustration, the machine consists of a platform, which moves on two sets of caterpillar traction wheels, and carries the machinery, A-frame, booms and dipper. The whole framework is constructed of steel. The engines of the regular, horizontal, friction-drum type are operated by a 25-h.p. gasoline engine, which consumes about 2 gal. of gasoline per hour. The boom is made in two sections; the main section and the movable section,

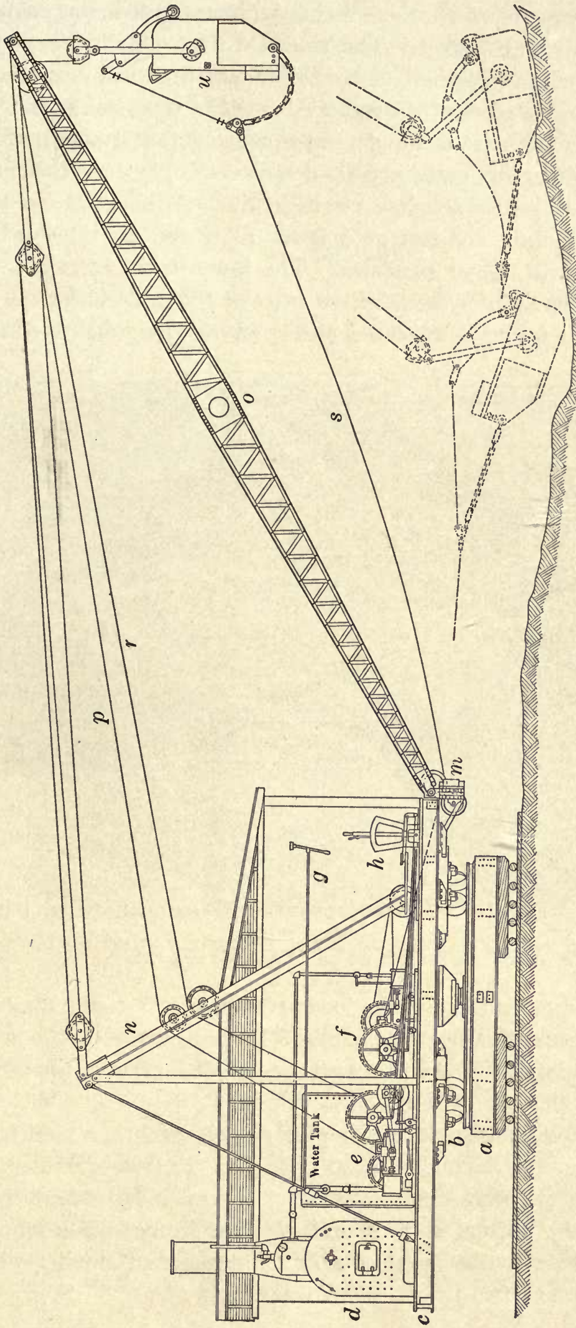
which is hinged to the main section near the lower end. The scraper bucket is fastened to a steel frame which is hinged to the movable section of the boom. In loading, the bucket is drawn down and toward the machine and when filled the movable and lower section of the boom is raised and hooked to the upper section. Then the whole boom is swung to one side and the dipper inverted and dumped. This machine operates a $\frac{3}{4}$-yd. dipper on a 20-ft. boom. One man is required to operate the machine. Its weight is about 12 tons, but on account of the distribution of the load over a large area of the surface by the platform wheels or caterpillar traction, the machine may be used on soft soil, which would support a man. Fig. 40 shows the caterpillar traction wheel.



Caterpillar Tractor of Gopher Ditcher.
Figure 40.

44. Scraper-bucket Excavator.—The best-known and most generally used type of dry-land machines, for the excavation of drainage ditches, is the revolving type of scraper-bucket excavator. This machine is built so as to run on a track or upon rollers, which move over planks set on the ground surface. The capacities of these excavators depend largely on the size of the bucket, which varies from $\frac{3}{4}$ cu. yd. to 3 cu. yd. It is not practical to use a bucket larger than 3 cu. yd. because this is the largest size that can be handled with speed and an economical use of power. Many manufacturers place the limiting size of bucket at $2\frac{1}{2}$ cu. yd. and the writer, from his experience, is inclined to agree with them.

The essential parts of a scraper-bucket excavator are the substructure, which consists of the upper and lower platforms and turn-



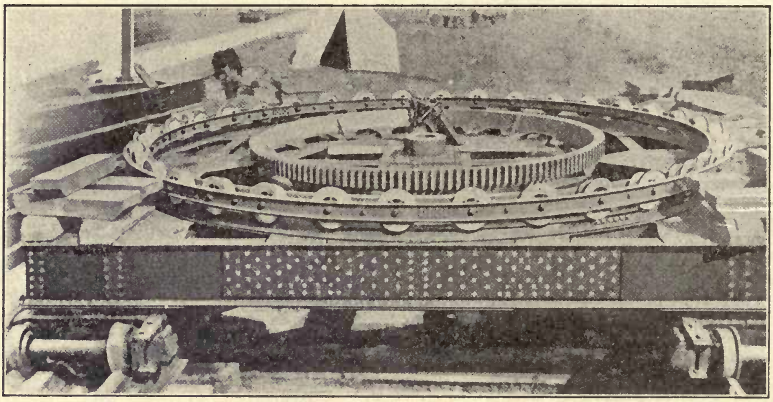
a, lower frame; *b*, turntable; *c*, upper frame; *d*, boiler; *e*, hoisting engine; *f*, swinging engine; *g* and *h*, operating levers; *m*, fair lead; *n*, A-frame; *o*, boom; *p*, boom fall line; *r*, hoisting line; *s*, drag line; *u*, bucket.

Detail View of Drag-line Excavator.

Figure 41.

table, the power equipment, the hoisting engines, the swinging engines, A-frame, boom and bucket. The essential parts and their system of coördination and method of operation are practically the same in all the various makes of the scraper-bucket or drag-line excavator. The only differences are in the details of construction, such as will be noted hereafter in the machinery and buckets. The principal parts of a drag-line excavator are shown in Fig. 41.

The sub-structure consists of a lower platform, an intermediate turntable and an upper platform. The lower frame consists of a rectangular-shaped open box, whose members are steel channels or I-beams. The frame is mounted either on wooden rollers, double-



Lower Frame of Drag-line Excavator.
Figure 42.

flanged truck wheels or four four-wheeled compensating trucks. Fig. 42 shows a typical make of lower frame mounted on the four-wheeled trucks.

Upon the upper surface of the lower platform is fastened the track upon which runs the swinging circle. In the center of the upper surface of the lower frame is fastened the female section of the central pivot.

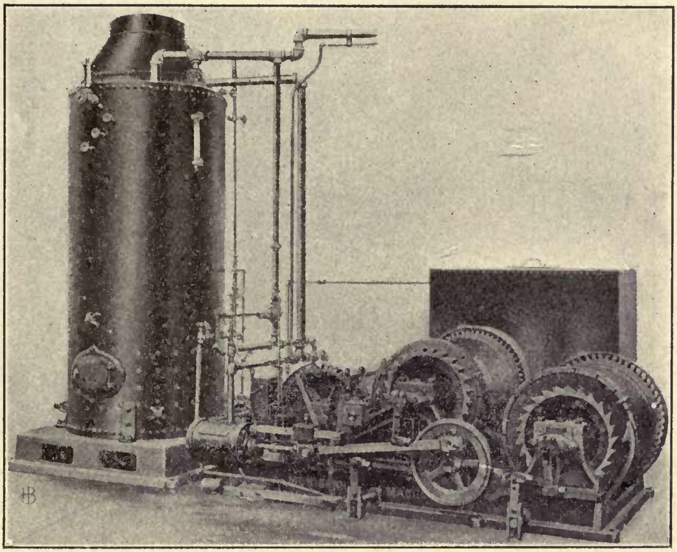
The turntable consists of a swinging circle, which is a steel frame supporting several flanged wheels. See Fig. 42. In one make of excavator the swinging circle consists of several independent trucks fastened to the bottom surface of the upper frame, while in other makes the circle is composed of a larger number of smaller wheels revolving between two tracks.

The upper framework or platform is built of steel channels and I-beams of lighter section than those in the lower frame. The various members are made in sections, which can be easily transported and readily assembled. Upon the lower surface of this frame is fastened the male section of the central pivot.

The power equipment may be made up on the basis of using steam, gasoline or electricity as the source of power.

BOILER

The steam equipment is the one generally used and will be described first. It consists of a boiler, steam pump, injector, water

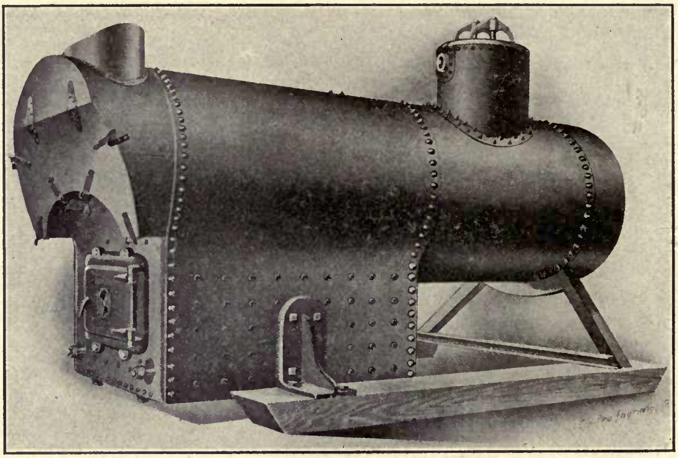


Boiler and Hoisting Engine of Drag-line Excavator.
Figure 43.

tank and piping. The style of boiler used depends on the power required. A vertical tube or brick-set boiler cannot be used. The gross horse-power required for the operation of the excavator should be estimated and 25 per cent. added to this amount to determine the rated horse-power of the boiler, which should be used.

It is often necessary where an excavator is at work in regions where the water supply is highly impregnated with salts, to purify the water before it is used in the boiler. This is best accomplished by running the water from the supply tank into a Feed Water Heater, where

escape steam from the boiler is used to heat the water to the boiling-point and this water after being freed of its salts and other impurities held in solution, is pumped into the boiler. This purification of the feed water prevents the incrustation of the boiler and thus greatly increases its efficiency. The writer has found that the use of "Boiler Compounds" or "Purgers" is at best an unsatisfactory and troublesome method of removing scale from boiler tubes. The only safe and reliable method is to remove the cause of incrustation before the water is admitted into the boiler. This will save time and expense in cleaning the boiler and also save coal. With a 100-h.p. boiler a



Locomotive Type of Boiler.
Figure 44.

Feed Water Heater having a height of 6 ft. 5 in. and a diameter of 24 in. would be of ample capacity. These dimensions will vary, however, with the type of heater used.

This surplus power is often needed under exceptional conditions such as excavation of very stiff or heavy soil, foaming of water in boiler tubes, excavation of frozen soil, use of poor-grade fuel, adverse atmospheric conditions, etc. On account of the high cost of fuel and the poor quality of water generally obtainable on drainage contracts, that type of boiler should be used that will give the greatest efficiency with the smallest fuel consumption. On the smaller size machines, a vertical boiler is generally used. Fig. 43 shows the boiler and hoisting engine used on a well-known make of excavator. On

the larger size machines, a return tube fire-box or locomotive type of boiler is generally used, as shown in Fig. 44.

A steam pump of the standard duplex type is generally connected to the boiler direct or to a water tank, which supplies the boiler by an injector.

MAIN ENGINE

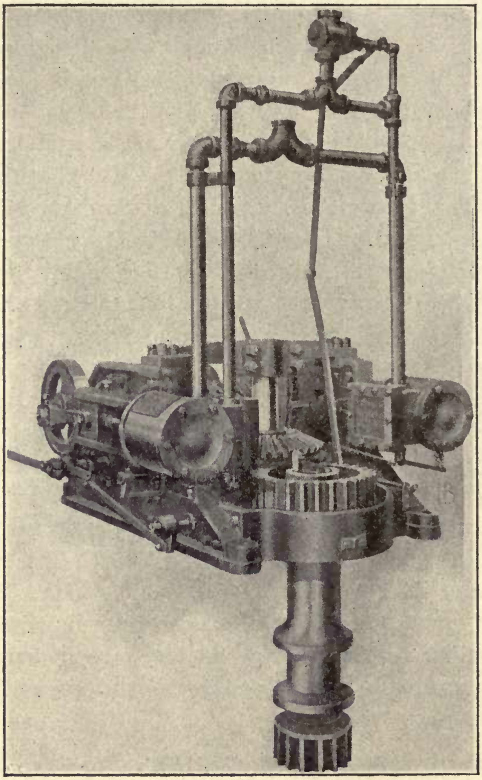
The hoisting engines, which are generally termed the main engines of an excavator, are generally horizontal, double-cylinder, friction drum type and self-contained on a single cast-iron or steel bed plate. The engine is always set directly in front of the boiler, with a narrow passage-way between. There is probably no severer test to which machinery can be put than that of dredging. The continued application for long periods of time of the shocks of throwing on and off the varying load is a very trying test of an engine's strength and durability. It is especially necessary that all gears be of steel, the shafts very heavy, the shaft and wrist pins large, and the front drum extra thickness and well braced inside. The writer has known of cases where the continual breaking of the various parts of an engine has caused serious delays and great loss of time and money to the contractor. The engine of some makes of excavator has three drums; the rear drum is used for handling the boom fall line, the center drum is for the hoisting line and the front drum for the drag line. See Fig. 43. In other makes of excavator, the engine has simply the hoisting and drag-line drums; the outer end of the boom being raised and lowered by a small winch, which is operated independently of the main engine. See Fig. 48. Some makes of engine provide double-band outside friction clutches actuated by auxiliary steam rams, which give a good control over the operation of the drums. This is necessary in the case of the drag line and hoisting drums.

SWINGING ENGINE

The mechanism for swinging the upper platform, machinery and boom, for propelling the excavator over the ground surface are sometimes contained in the main engine. Some manufacturers, however, provide a separate swinging engine, self-contained on its own base plate. This engine is of the steam reverse type and drives through a chain of gears, a pinion which operates the large circular rack on the lower frame. The swinging engine used on a well-known make of drag-line excavator is shown in Fig. 45. The swinging engine should be provided with some device for keeping the swinging lines tight. To

insure smoothness of operation, an auxiliary steam cylinder should be connected to the tumbling shaft. The cylinder and throttle are generally operated by a single lever.

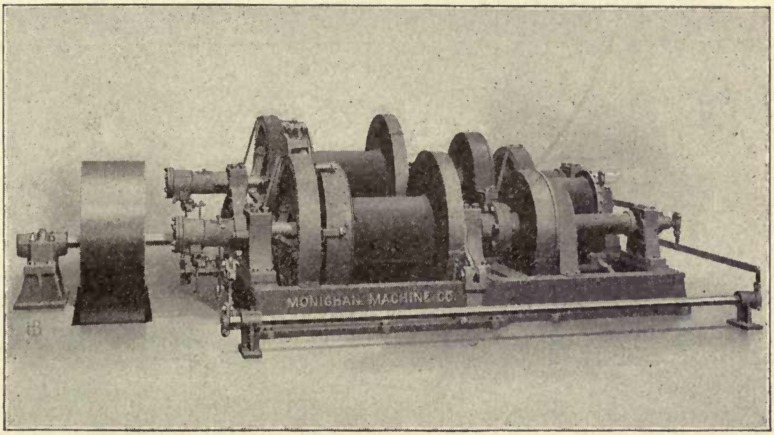
In Minnesota and South Dakota in recent years (1907–13), gasoline and kerosene engines have been used for the driving of the machinery of drag-line excavators. The engine is mounted on a base just in the



Swinging Engine of Drag-line excavator.
Figure 45.

rear of the engine to which it is belt connected. The drums of the engine are provided with outside band friction clutches, which are controlled by pneumatic thrust cylinders. The swinging mechanism is mounted on the same base and to one side of the hoisting and drag-line drums. Double-cone friction clutches are used to operate the swinging drums.

The gasoline engine should have a capacity of 40 to 50 h.p. for an excavator with a $1\frac{3}{4}$ cu. yd. to a $2\frac{1}{2}$ cu. yd. bucket. As is well known, the internal combustion engine should be mounted on a stable and rigid base for efficient and uniform operation. On the upper platform of a drag-line excavator, the engine is subjected to severe shocks and vibration and such parts as the crank, crank pin, main shaft, governor, etc., must be made of extra heavy section and weight to resist the unusually severe strains. The writer has seen the Otto and Stickney engines used on $2\frac{1}{4}$- and $2\frac{1}{2}$-yd. bucket excavators, and even with these heavily built engines, the breaks have been numerous. It is



Mechanism for Drag-line Excavator operated by Gasoline or Electric Power.
Figure 46.

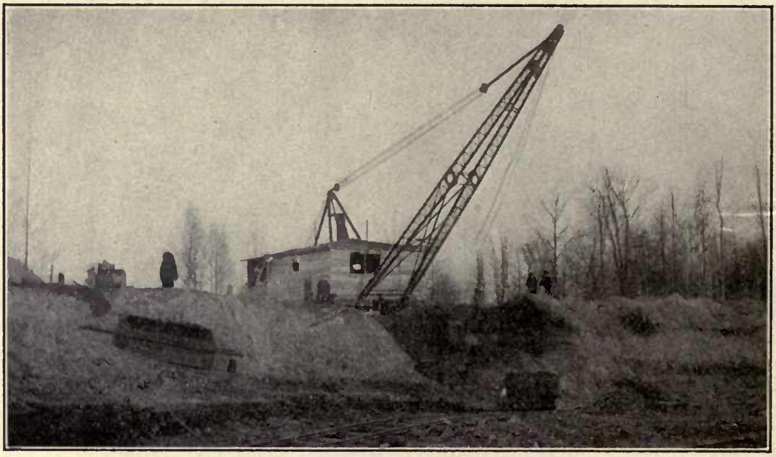
especially necessary that a liberal excess of power be used and experience has proven the wisdom of using not less than 50-per cent. horsepower in excess of that estimated.

A small air compressor actuated by a belt connection with the engine, furnishes compressed air to a receiving tank. The air is then supplied to the thrust cylinders, which control the band friction clutches on the drums. A water tank for supplying water to cool the cylinder of the engine and a gasoline supply tank are also placed on the upper platform near the engine. The gasoline engine is much more economical to operate than a steam equipment in localities where coal is expensive and requires long and costly hauling and also where water is scarce and poor in quality.

Where electric power may be obtained at moderate cost and near at hand, it would be advisable to install an electric generator and belt-connect this to the main engine shaft. This kind of power is the cleanest and easiest to handle and does away with the expense and trouble of handling coal or oil and requires very little attention. On work near large cities or in the vicinity of a power transmission line, electric power should be used.

The hoisting, dragging and swinging mechanism to be used in connection with gasoline and electric power is shown in Fig. 46.

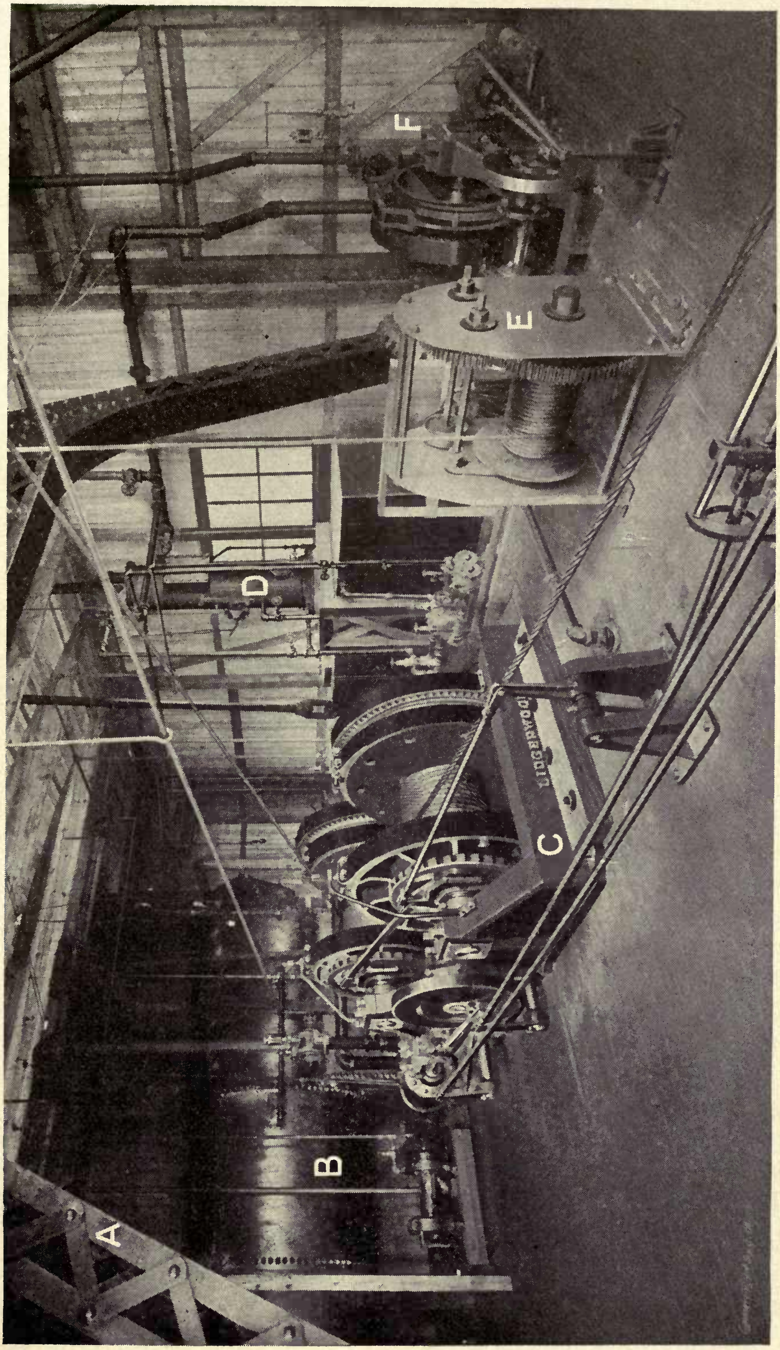
The assembled machinery on a drag-line excavator in operation is shown in Fig. 48, which is a view of the interior of the engine house.



Drag-line Excavator with Steel-framed Boom.
Figure 47.

BOOM

The boom or crane is composed of a structural steel framework, generally two channels braced together for the smaller excavators and two latticed girders braced together for the larger excavators. See Fig. 47. The lower ends of the main members, channels or latticed girders, are spread apart at the lower ends and hinged to the outer corners of the front side of the upper platform. The upper ends of the main members are joined together so as to form a boxing wherein one or more sheaves are placed. The main members are cross braced with small lateral trusses so designed as to resist the severe lateral



A, "A" frame; B, boiler; C, hoisting engine; D, feed water heater; E, deck winch; F, swinging engine.
Interior View of Engine House of Drag-line Excavator.
Figure 48.

strains occasioned by the sudden starting and stopping of the swinging of the boom.

A-FRAME

The top of the boom is connected by cables with the top of a vertical frame called an "A"-frame. This frame is located near the front end of the main engine and the lower ends are bolted to the sides of the upper platform, while the upper ends are framed together to form a boxing for a sheave. The top of the "A"-frame is guyed back to the two rear corners of the upper platform. The top of the boom may be raised or lowered by means of a wire cable, which passes from the end of the boom over the sheave at the top of the "A"-frame and thence down to a winch on the floor of the house. See Figs. 41 and 48.

The bucket may be one of three types: the scraper bucket, the clam-shell bucket and the orange-peel bucket. The last two types are only used for special work such as rock excavation (rock previously loosened by blasting) narrow trench or ditch excavation, etc. The dimensions, weights and cost of these two types are given in Figs. 24 and 25.

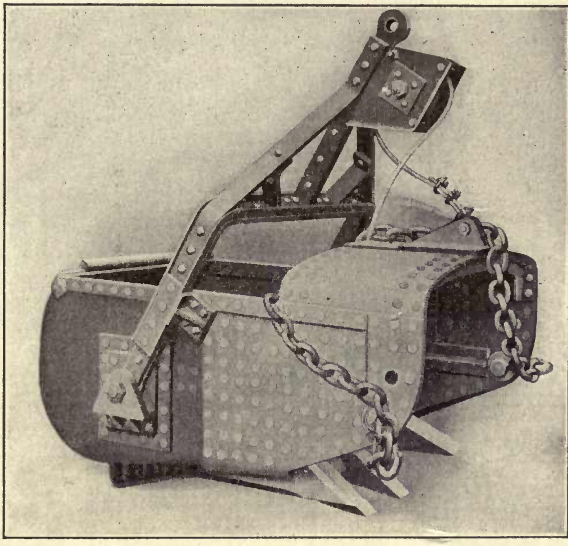
BUCKET

The scraper bucket is the type in general use with a drag-line excavator, and as the name of the machine implies, the bucket is filled by dragging the bucket toward the machine by a line or cable. There are several different makes or styles of these scraper buckets, which differ only in their details of construction. These various types are: the Page bucket, the Martinson bucket, the Browning bucket, the Austin bucket, and the Bucyrus bucket.

The "Page" bucket is shown in Fig. 49, and is operated as follows: the drag line, attached to the bail of the bucket and then back to the front drum of the main engine, is drawn toward the machine until the bucket is filled. The foot brake is then set and the friction clutch applied to the front drum, which becomes stationary. The control of the second or hoisting drum is then released and the bucket hoisted by the application of power to and the winding up of the hauling cable on the drum; meanwhile the friction clutch on the front drum is released by the foot brake and the drag line is allowed to unwind from the drum. The power to the swinging engine is then applied and the upper platform is revolved until the dumping place

is reached by the bucket. The clutch of the hoisting drum is then released and the bucket dropped to the ground, when it assumes a vertical position and discharges its contents.

The Martinson bucket or generally known as the Monighan scraper bucket is very similar to the Page bucket and like it is a two-line appliance. The operation of the machinery for digging, swinging and dumping is the same as described above for the Page bucket. The drag line, in the case of the Page bucket, is fastened to the top of the front end of the bucket, thence passes up over a small sheave



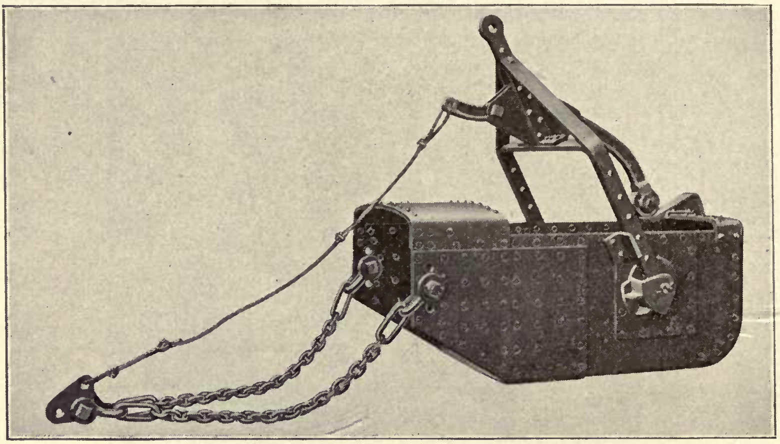
"Page" Scraper Bucket.
Figure 49.

in the upper part of the bail and thence out to a connection with the two side chains and from here to the front drum. A reference to Fig. 50 will show that in the use of the Monighan bucket, the bucket is held horizontally by the lever mechanism which is connected to the drag line by a cable. When the bucket is dropped and the drag line released, the bucket assumes a vertical position and dumps by gravity.

The Browning scraper bucket has two hoisting lines besides the drag line; one attached to the end of the bail and the other fastened to the rear of the bucket. The drag line is fastened to a bail, which projects in front of the bucket and which may be set at different

angles to the bottom of the bucket. The dimensions, weights and costs of the various sizes are given in Fig. 51.

The Austin scraper bucket is a two-line excavator similar to the Page bucket. The distinctive feature of this bucket is a latch, which hooks over a pin on the front end and maintains it in a horizontal position. The bucket may be dumped at any position by releasing the latch and allowing the bucket to assume a vertical position and dump the contents.



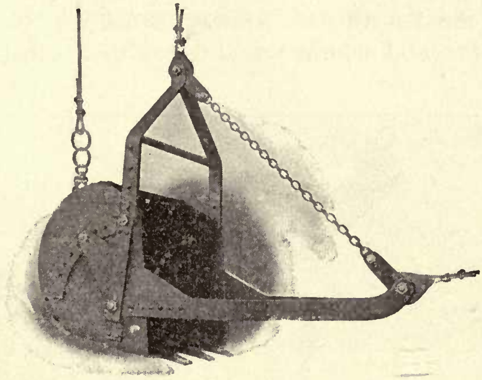
"Monighan" Two-line Drag Bucket.
Figure 50.

The Bucyrus scraper bucket is very similar to the Browning bucket shown in Fig. 51. The distinctive features are a rigid bail connection for the drag line and a rounded back. By varying the angle, which the drag-line bail makes with the bottom of the bucket, a downward force may be exerted and assist in the excavation of stiff material. The rounded back is of advantage in the excavation of sticky or gumbo soil, as the material will not stick to the bucket and the material as it is excavated is rolled up and decreases the resistance to the loading up of the bucket.

A novel bucket has recently been devised and put on the market by M. S. Iverson of New York. The improvements claimed for this bucket by the inventor to give it superiority in construction and operation over all other types of drag-line buckets are as follows:

The elimination of the tension between the drag line and the hoist line, while the bucket is being hoisted to the dumping place.

This is effected by the use of a latching device which automatically hooks over the bail of the bucket, when the latter is pulled forward by the drag line. Thus the bucket may be hoisted from any position in relation to its distance from the end of the boom. Fig. 52 shows



Capacity Cu. Yd.	Extreme Length	Extreme Height	Extreme Width	Hoist Rope	Dump Rope	Drag Rope	Weight and Price
¾	7-6	6-1	4-4	⅝	⅝	¾	1500 lbs. **$500.00**
1	8-3	7-0	4-9	¾	¾	¾	2000 lbs. **$525.00**
1½	10-3	8-5	5-0	¾	¾	⅞	2850 lbs. **$550.00**
2	11-2	9-8	5-3	⅞	¾	1	3800 lbs. **$650.00**
2½	11-6	10-9	5-9	⅞	⅞	1⅛	4750 lbs. **$800.00**
3	12-0	12-0	6-3	⅞	⅞	1¼	5900 lbs. **$1000.00**
3½							

Browning Scraper Buckets.
Figure 51.

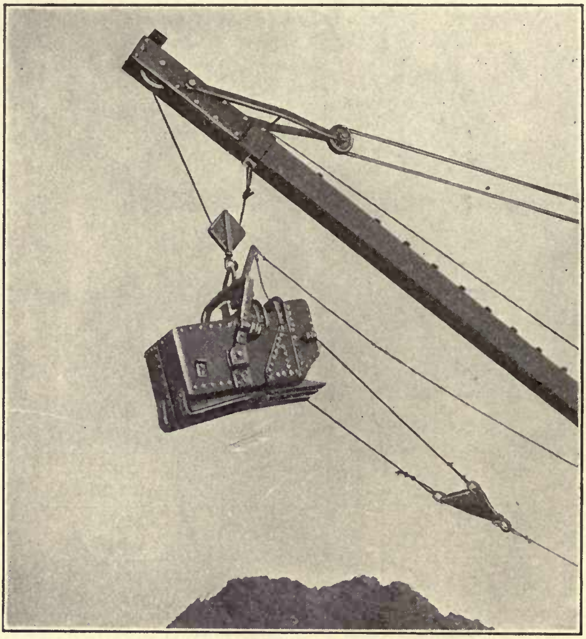
the bucket being hoisted over the spoil bank by the hoist line alone; the drag line being slack.

The reduction of repairs on the bucket, due to the design and improved methods of construction.

The reduction of weight on the bucket on account of the elimination of the drag-line strain.

The resulting increase in size of the bucket on account of the reduction of work which the machine is subjected to, by the use of the tension feature.

The following quotation from a letter of a contractor, who used the Iverson bucket in excavation work connected with the construction of the Fourth Ave. Subway, Brooklyn, N. Y., will give the results of several months actual test of this bucket.

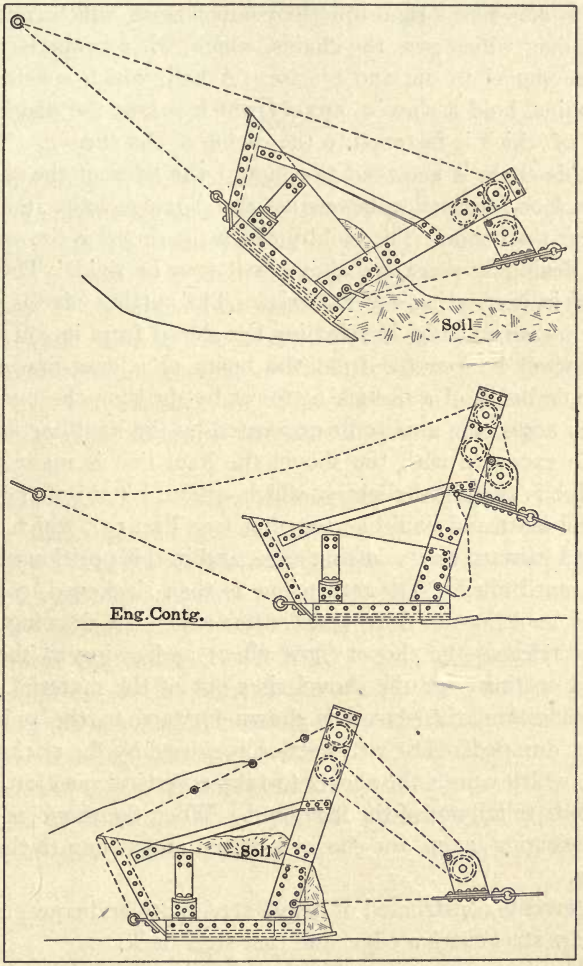


"Iverson" Bucket.
Figure 52.

"The bucket possesses two features which will figure to a great advantage against any other drag-line bucket, the most important feature that of doing away with the tension between the drag line and the lift line (since the bucket is a locked one) and the second feature that of preventing the compression on the front of the bucket, thereby doing away with a lot of useless reinforcement, has proven to be of such a great advantage to the machine operating the bucket that our own Browning crane can do a good day's work with 65 lb. of steam with this new bucket whereas other buckets would stall in the bank with 85 lb. and would require 100 lb. of steam to do the same work."

The bucket is made in $\frac{1}{2}$, $\frac{3}{4}$, 1, 1 $\frac{1}{2}$, 2, 2 $\frac{1}{2}$ and 3 cu. yd. capacities and equipped with either forged or manganese steel teeth.

A shovel which has been in successful operation for several years on the Pacific Coast is the Weeks shovel. The principles involved



"Weeks" Drag-line Bucket.
Figure 53.

in its construction and operation can be understood by a reference to the line drawings shown in Fig. 53.

Like all other buckets of this type, it is operated by two lines, a

drag or haul line, which pulls the bucket forward and a return line to draw it back. The body of the shovel or bucket consists of a pan, open at the top and front, a sloping back to facilitate the return of the shovel after dumping and lugs attached to the vertical sides for use in dumping the load forward. To the front part of the sides of the pan is attached a rigid upright yoke or mast, which contains two sheaves, over which pass the chains, which, when properly operated, cause the shovel to dig and release. A bail, which consists of two short chains, hold a sheave, around which passes the digging chain, one end of which is fastened to the casing of the sheave. The other end of this chain is attached to a lug at the back of the shovel and the rehaul or return line fastens to the digging chain at a suitable point near the boom. The bail by which the shovel is drawn forward may be flexible as described above or it may be rigid. The latter is preferred in excavating soft material. The cutting edge is generally curved upward to assist in releasing the shovel from its cut.

The shovel is operated from the boom of a drag-line excavator or a simple boom of a derrick or tower by drawing the bucket back and forth across the area to be excavated by the haul line and return line. To excavate with the shovel the haul line is made taut, the return line is tightened slightly, which action, by aid of the sheaves, draws the mast and haul line together (see Fig. 53), which thus tips the shovel forward on its cutting edge, and in this position it is drawn forward until filled. The return line is then slackened, causing the mast and haul lines to draw apart, after which the drawing in of the haul line releases the shovel (now filled) and owing to the slightly upturned cutting edge the shovel rises out of the material. In this loaded condition, the shovel is drawn forward to the point where it is to be dumped. The latter action is caused by the slacking of the tail line, which causes the shovel to take a vertical position, allowing its contents to fall out of the front end. When the shovel is operated from a swinging boom, the shovel is raised and swung to the side for dumping.

The shovel is constructed of heavy steel plate and equipped with a manganese steel cutting edge, and cast steel back.

The shovels are constructed in the following sizes and weights:

Size	Weight
15 cu. ft.	1,520 lbs.
22 cu. ft.	2,120 lbs.
34 cu. ft.	3,050 lbs.
42 cu. ft.	4,100 lbs.

The 34 cu. ft. is the size generally used and is usually operated by means of an $8\frac{1}{4} \times 10$-in. double-drum hoisting engine, requiring from 35 to 60 h.p. depending on the kind of material to be excavated.

The capacity of the shovel varies from 350 to 500 cu. yd. per 10-hour day. Three men are generally required in an ordinary crew, one to operate the shovel, one to operate the boiler, and a general laborer.

CABLES

The experience of most contractors (including some noted above), in the use of drag-line excavators, is that the principal source of expense for repairs is in the wearing out of cables. The drag-line cable especially is subject to great wear in passing over the guide sheaves on the front of the upper platform. These guide sheaves are called the "fair lead" and in the latest form, consist of two horizontal sheaves mounted on a casting on which is pivoted a swinging frame, carrying two vertical sheaves. This frame, in revolving, will take the direction of the drag line and thus maintain a straight lead at all times.

The drag-line and hoisting cables are continually subjected to vibratory stress and shocks and should be made of the very best plow steel. There are several, well-known brands or makes, generally designated by a colored strand woven into the cable and thus deriving the names, "red strand," "yellow strand," etc.

45. Typical Operating Cost.—With a 2-cu. yd. bucket, drag-line excavator, an excavation of from 800 to 1,200 cu. yd. should be made in a 10-hour working day; depending on the character of soil excavated, the length of swing, the cross-section of the ditch or canal and the experience and ability of the operator.

The cost of operation of a 2-cu. yd. excavator for a 10-hour day would be about as follows:

Labor:

1 operator	$5.00	
1 fireman	3.00	
4 laborers @ $2,	8.00	
1 teamster,	2.00	
1 cook,	1.50	
Total labor,		$19.50

Miscellaneous:

Board and lodging for crew,	4.00
Repairs, oil, waste, etc.,	6.00
2 tons of coal @ $6.50	13.00
Overhead expenses,	12.00
Total,	$54.50

Assuming that 1,000 cu. yd. is the average daily excavation, the cost per cubic yard would be 5.45 cents.

45a. Use in South Dakota.—During the latter part of the year 1911, a $2\frac{1}{4}$-cu. yd. bucket, drag-line excavator was used in the excavation of a section of ditch in the lower Vermilion River Valley, Clay County, South Dakota. The cross-section excavated had a bottom width of 20 ft., average depth of 8 ft., and side slopes of 1 to 1. The material excavated was loam and clay, there being an alluvial deposit of about six feet of loam underlaid with yellow clay.

The total working time was 148 days of 22 hours each; there being two shifts of about 11 hours each. The total amount of excavation was 222,494 cu. yd., or an average daily rate of 1,503 cu. yd. and an average hourly rate of 68 cu. yd.

A tabulated list of operating expenses is given below:

Labor:

Scale of Wages

Operator,	$125.00 per month.
2 cranesmen, @ $100,	200.00 per month.
4 laborers, @ $50,	200.00 per month.
1 teamster,	50.00 per month.
1 cook,	35.00 per month.
Total cost of labor,	$3,060.00 per month.
Cost of labor per cubic yards excavated,	1.38 cents.

Fuel:

15,444.8 gal. of gasoline @ 12.4 cents,	$1915.15.
Cost of fuel per cubic yard excavated,	0.86 cent.

Cable:

First quality steel wire rope, $\frac{7}{8}$ in., for hoisting and swinging cables, and $1\frac{1}{4}$ in., for drag-line cable.

Total cost of wire rope,	$978.87
Cost of wire rope per cubic yard excavated,	0.44 cent.

Repairs and Renewals of Machinery:

Repairs and Renewals of machinery

Bucket bailers, friction blocks, sheaves, etc., etc.

Total cost of repairs and renewals,	$845.93
Cost of repairs and renewals per cubic yard excavated,	0.38 cent.

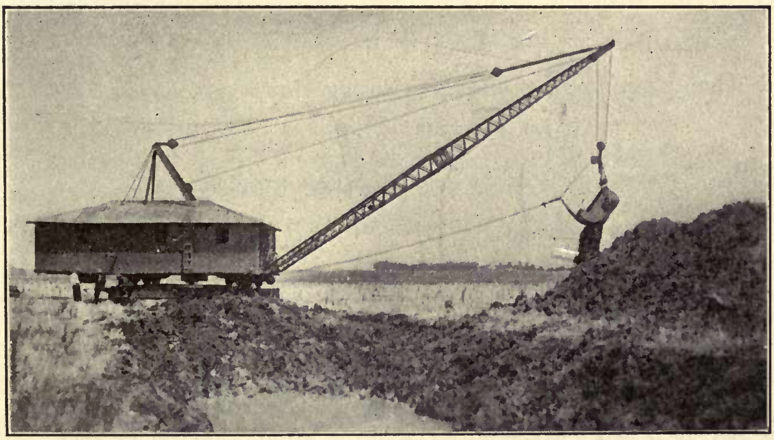
Board and Lodging:

Total cost of board and lodging of 9 men for full time of 148 days,	$561.81
Cost of board and lodging per cubic yard excavated,	0.25 cents.

Miscellaneous:

Livery, horse keep. hardware, lumber, oil, grease, waste, freight, express, etc., etc. (not including general office expenses, depreciation, insurance and interest on investment).	
Total cost of miscellaneous,	$2,078.72
Cost of miscellaneous per cubic yard excavated,	0.93 cent.
Total amount of operating expenses,	$9,440.48
Cost of operating excavator per working day,	$63.79
Cost of operating excavator per cubic yard excavated,	4.24 cents.
Initial cost of excavator, moving, setting up, taking down, etc.,	$10,500.00
Contract price for work,	7 cents per cubic yard.

The drag-line excavator was made by the Monighan Machine Company of Chicago, Ill., and used a 50-h.p. Otto gasoline engine for



Drag-line Excavator excavating Large Drainage Ditch.
Figure 54.

power. The boom had a length of 60 ft. and the $2\frac{1}{4}$-cu. yd. scraper bucket was of the Martinson type, as shown in Fig. 50. A view of this excavator in operation is given in Fig. 54.

45b. Use on New York State Barge Canal.—During the season of 1908, a drag-line excavator with an 85-ft. boom and a 2-yd. dipper was

used on a section of the New York State Barge Canal. The machine was equipped with an engine of 50-h.p. capacity and a boiler of 54 h.p. The total weight of the excavator was 147 tons and cost $10,000.

The following table gives the cost of operating the machine during the season of 1908 and also the cost of excavation per cubic yard.

TABLE XVII
COST OF EXCAVATION OF CANAL

Character of work	April	May	June	July	August
Fitting up	$426.80	....	....	....	....
Excavation	319.74	$684.29	$747.77	$850.69	$1,118.57
Repairs	....	15.82	62.60	48.23	75.12
Interest and depreciation, 21 per cent.	175.00	175.00	175.00	175.00	175.00
Shifting on work	....	(a)	....	77.02	....
Total for month	$921.54	$875.11	$985.37	$1,150.94	$1 ,368.69
Average cost per yard	$0.177	$0.048	$0.0388	$0.0348	$0.0289
Yards completed during month	5,205	18,365	25,333	33,055	47,36

(a) Work delayed due to accident.

The itemized cost of operation during May is as follows:

Engineer, @ $90 per month,	$90.00
Engineer, @ $95,	84.04
Firemen, pump men, watchmen, and laborers @ $1.75 per day,	363.00
Coal at $3 per ton,	147.00
Repairs,	15.82
Total,	$699.86

The canal was 100 ft. wide on the bottom, side slopes of $1\frac{1}{2}$ to 1, and average depth of 25 ft. The material excavated was stiff clay. A few boulders and stumps were removed.

The average cost of excavation, including an estimate for interest and depreciation, was 4.1 cents per cubic yard.

45c. Use in Florida.—During the years 1911, 1912 and the present one of 1913, a large outlet canal is being excavated by four drag-line excavators. The work is located near Sebastian on the east coast of Florida and the material excavated is sand and shell marl. The ditch or canal is $4\frac{1}{2}$ miles long, has a bottom of 50 ft., depth varying from 10 to 18 ft., and side slopes of 2 to 1. Berms of 20 ft. were left along the sides of the ditch.

The four excavators each had a bucket capacity of $1\frac{1}{2}$ cu. yd. and a boom length of 70 ft. The excavators were of standard make and used complete steam equipments. The machines worked in pairs on opposite sides of the canal and excavated to a fairly uniform grade and even side slopes.

During the five months from May to November, 1911 (inclusive), the four excavators together excavated on the average, 111,210 cu. yd. per month or 27,800 cu. yd. for each excavator per month. Two shifts, of 10 hours each per day, were worked, and the average excavation per machine for each shift was 620 cu. yd. The total yardage excavated during the year 1911 was 1,023,662 cu. yd., one machine working 12 months, two machines working 11 months, three machines working 10 months and four machines working 9 months.

The entire labor organization when the four machines were working together was as follows:

1 superintendent of works,
1 master mechanic,
9 operators,
4 roller gang foremen,
32 laborers in roller gangs (negroes),
8 firemen (negroes),
1 oiler,
1 blacksmith,
1 assistant blacksmith,
2 pump men,
2 pipe line men,
3 teamsters, $\begin{cases} \text{6 mules,} \\ \text{1 horse,} \end{cases}$
2 cooks,
1 yard man,
2 dynamite men,
7 general laborers (negroes),

The fuel used was pine wood, which had been partially seasoned. About 2 cords of wood were used for each excavator per shift.

The following table gives a brief statement of the cost of operation.

Operating costs,	$67,645.19
Board and lodging,	6,137.85
Repairs and renewals,	7,131.02
Stable upkeep,	1,527.94
	$82,442.00
Average cost of excavation (based on a total excavation of 1,023,662 cu. yd.),	8.05 cents per cubic yard.

The above estimate does not include depreciation or overhead charges.

45d. Use in Nevada.—The Reclamation Service is using (1912) a drag-line excavator in the construction of canals and embankments on the Truckee-Carson project, near Fallon, Nevada. The excavator is equipped with a 14-ft. roller circle, a 60-ft. structural steel boom and a $1\frac{1}{2}$-cu. yd. three-line, scraper bucket. The machine is equipped with electric motors throughout, using alternating current

at 440 volts. The current is generated at a hydro-electric plant located on the main canal of the project. The cost of this electric power would be equivalent to coal at about $2 per ton. Steam-coal at this place would cost $9 per ton, delivered on the excavator.

The average capacity of the machine, excavating gravel, clay and loam under ordinary conditions, is about 500 cu. yd. per 10-hour day. It requires the services of one operator on the machine and two trackmen and laborers on the ground to operate the excavator.

45e. Use in California.—A drag-line excavator was used in 1912 in the construction of ditches and levees near Buttonwillow, California. The minimum width of base of canal or levee is 30 ft., while the minimum height of levee is 6 ft. and depth of ditch is 4 ft. The material excavated is clay and loam and most of the digging is in fairly dry soil.

The excavator is equipped with 100-ft. boom and a 3½-cu. yd., three-line scraper bucket. California crude oil is used as fuel and the average consumption is 800 gal. per day. At 2 cents per gallon, the daily cost for fuel amounts to $16. The cost of labor and subsistence amounts to $75 per day.

Two 11-hour shifts are employed in the operation of the excavator and the average daily excavation is 2,000 cu. yd.

During the year, April, 1909 to April, 1910, a diverting canal was excavated near Stoelston, California, to connect the Mormon slough to the Calaveras River. This canal had a length of 5.25 miles, a bottom width of 150 ft., an average depth of 10 ft. and side slopes of 1 to 1. The material excavated was a heavy black loam underlaid with clay, which was very hard in spots.[1]

The excavating machinery used on this work consisted of a Heyworth-Newman drag-line excavator, equipped with a 100-ft. boom and a 3½-cu. yd. bucket; and a clam-shell machine with a 110-ft. boom and converted into a drag-line excavator with a 2½ cu. yd. bucket.

One excavator was set up and worked at a distance of 7 ft. from the center line of the canal and excavated the outer 30 ft. of the canal width and deposited the excavated material clear of the berm. A length of 2,000 ft. was worked in this manner and the excavator was then moved in about 31 ft. and another parallel section was taken out up to 7 ft. of the other side of the canal. The converted clam-shell excavator followed and completed the excavation.

[1] Engineering-Contracting, July 20, 1910.

The machines were equipped with boilers, burning crude oil for fuel. The oil cost $1 per barrel and each machine used about 17 gal. per hour, which would make a total daily cost of fuel for each machine of $7.48. This, of course, makes a fuel cost much less than of coal, and oil is much easier and better to handle than coal.

Water for the boilers was secured by boring wells about every 4,000 ft. along the line of the canal. A pumping plant equipped with Worthington duplex pumps, was used to force the water from the wells through a 14-in. pipe line to the boilers. Even this well water was so heavy with salts that it required a weekly shutdown for cleaning the boilers and general repairs.

The excavators worked in two shifts of 11 hours each; Sundays being spent in the cleaning out of the boilers and the making of general repairs.

The labor organization was as follows:

1 superintendent,
2 captains, one on each machine,
3 leveemen, 6 hours on and 12 off,
2 mates, one on each machine,
4 firemen, 2 on each machine,
8 deckhands, 4 on each machine,
1 blacksmith,
1 helper,
1 cook,
1 flunkey,
2 pumpmen,
1 handyman,
1 team of 6 horses for hauling.

During the 13 months from April, 1909 to April, 1910, inclusive, the Heyworth-Newman drag-line excavator made a total excavation of 437,873 cu. yd. or an average of 33,683 cu. yd. per month. The converted clam-shell excavator, during the same period, made a total excavation of 242,600 cu. yd. or a monthly average of 24,260 cu. yd. The monthly average for the two machines was 57,973 cu. yd.

The cost of operation per month was as follows:

Pay-roll,	$3,754.00
Fuel oil,	945.00
Lubricating oil and repairs,	2,220.00
Total cost of operation for both machines,	$6,919.00
Cost of operation per cubic yard excavated,	11.9 cents.
Contract price for work, per cubic yard,	15.5 cents.

A dry-land excavator of simple design but rather unusual in this make-up, was used during the seasons of 1907 and 1908 in the excavation of drainage ditches in the Turlock and Modesto irrigation districts of the San Joaquin Valley, California.

The dredge consisted of a timber platform 18 by 30 ft. mounted on skids which rested on wooden rollers.

These rollers moved on planks placed on the ground and thus provided for the movement of the dredge along the line of the ditch. This was effected by means of a steel cable anchored to a "dead man" ahead of the dredge and wound on a drum, which was power driven by a worm gear from the main engine. The dredge was moved 3 to 5 ft. at a time as the ditch was excavated. At the front end of the platform was placed a timber A-frame, 20 ft. high. At the center of the front platform was pivoted a cable-propelled turntable, which carried the foot of a 40-ft. timber boom. This boom was hung at an angle of 45 degrees from the peak of the A-frame by wire cables. From a set of sheaves at the outer end of the boom, was suspended the bucket. This was a clam-shell bucket of 1 cu. yd. capacity and weighing about 2,800 lb. Power was furnished by a 25-h.p. single cylinder gasoline engine, which drove a standard combination gear and friction brake drum dredging engine. This engine was controlled by means of three levers and two foot brakes from a platform just back of the swinging circle. The initial cost of the dredge was about $5,000.

The ditches were about 20 ft. wide at the surface and were made with as steep side slopes as was practicable. The depth of cut varied from 5½ to 10 ft. A 6-ft. berm was left and at first the excavated material was all placed on one side of the ditch. Through the higher land at the upper end of the ditch it was found necessary to waste the material on both sides of the ditch. The banks caved so that a bottom width of about 6 ft. was left for the ditches. The ditches connected several swales separated by sand "blows." Below the surface soil of coarse sand and gravel was a 3-ft. layer of clay underlaid with fine quicksand. In the Turlock district the uplands were of a sandy soil, while at the foot of the slope near the river was a compact adobe. In places was found a dike of hard gray hard-pan in a wave-like form. Several crests of considerable thickness outcropped in places and required blasting where the ditch passed through.

Following is given a table showing the cost of excavation for one month of the Modesto drainage canal.

Labor:

Foreman,	$95.00
Assistant foreman,	85.00
Swamper,	50.00
Swamper, one-half time,	25.00
Man and team, one-half time,	50.00
Total labor cost,	$305.00

Supplies:

400-ft. $\frac{3}{8}$-in. hoisting cable,	$50.40	
$6\frac{1}{2}$ gal. gasoline,	1.60	
3 gal. lubricating oil,	3.75	
5 lb. Hecla compound,	1.25	
595 gal. distillate, @ $7\frac{1}{2}$ cents per gallon,	44.62	
1 cylinder cup,	3.00	
Rollers,	21.00	
Large intermediate gear,	14.00	
172 lb. dynamite, @ 16 cents per lb.,	27.52	
1,000-ft. fuse,	7.50	
2 boxes caps,	1.60	
Depreciation of dredge (10 per cent. of $5,000),	40.00	
Total material and general cost,		$216.24
Total cost,		$521.24
Total excavation,	14,941 cu. yd.	
Cost of excavation per cubic yard,	$0.035	
Operation cost per hour (based on 255 hours),		$2.05
Operation cost per hour (based on 200 hours),		2.61
Cubic yards excavated per hour (based on 255 hours),		58.6
Cubic yards excavated per hour (based on 200 hours),		74.7

It is interesting to note here that a small drainage ditch excavated with teams and scrapers in the Turlock district cost 8 cents per cubic yard for sand and clay and 50 cents per cubic yard for hard pan.

45f. Use on New York State Barge Canal.[1]—Three drag-line excavators were used in earth excavation on Contract No. 42 of the New York State Barge Canal, during April, 1910. The material excavated was principally a heavy gumbo soil.

Two of the excavators were electrically driven Lidgerwood-Crawford drag-line machines, equipped with 100-ft. booms and $2\frac{1}{2}$-cu. yd. "Page" buckets. The engines were driven by a 25-h.p. motor for swinging and a 125-h.p. motor for hoisting. City current was used and cost about 1 cent per cubic yard of material excavated. These machines moved about during the month and most of their excavation was superficial. Excavator No. 1 worked 13 days and Excavator No. 2 worked 10 days during the month.

The other machine was a Heyworth-Newman drag-line excavator operated by steam power and equipped with a 100-ft. boom and a $2\frac{1}{2}$-cu. yd. bucket.

All the excavators worked in three shifts of eight hours each.

[1] Engineering-Contracting, Sept. 28, 1910.

Following is a tabulated statement of the cost of labor and excavation for these three machines.

Heyworth-Newman Excavator

1 operator,	$4.00
1 fireman,	2.00
5 laborers, @ $1.50,	7.50
1 foreman, average $85 per month,	2.83
1 pumpman,	1.50
1 oiler,	2.00
1 team for 1 shift per day,	4.50
Total cost of labor per day,	$24.33
Total Cost of excavation per month,	$1,983.84
Total cubic yards excavated for month,	23,192
Cost of excavation per cubic yard,	$0.085

Two Lidgerwood-Crawford Excavators (Labor for Each machine)

1 operator,	$4.00
1 oiler,	2.00
5 laborers, @ $1.50	7.50
1 sloper,	2.25
1 foreman, @ $85 per month,	2.83
1 electrician @ $125 per month,	4.17
Total cost of labor per day for each machine,	$22.75

Excavator No. 1

Total cost of excavation for month,	$1,667.80
Total cubic yards excavated for month,	2,271
Cost of excavation per cubic yard,	$0.735

Excavator No. 2

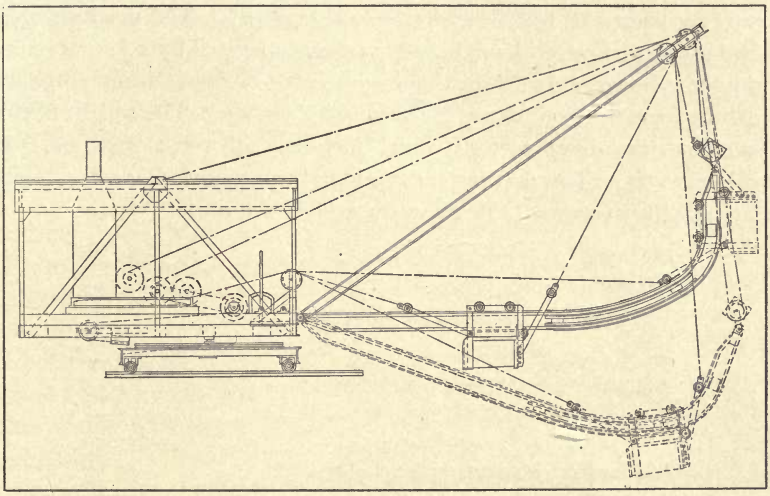
Total cost of excavation for month,	$992.30
Total cubic yards excavated for month,	2,583
Cost of excavation per cubic yard,	$0.384

46. Jacobs Guided-Line Excavator.—In the use of the ordinary drag-line bucket excavator, difficulty is often experienced in guiding the bucket when stiff material is encountered. This difficulty is especially noticeable when the bucket is cutting the sloping banks of an open ditch and the bucket, in its upward path, passes from stiff to loose material. Recently an excavator has been put upon the market designed to overcome this difficulty. This new machine is the Jacobs Guided-Drag-Line-Bucket-Excavator, manufactured by the Jacobs Engineering Co., of Ottawa, Ill.

This excavator consists of a steel-framed platform made up of stand-

ard structural steel shapes, which are joined with fitting bolts. This upper platform revolves on a circular track, which rests on a lower steel-framed platform. The machinery consists of a three-drum hoist with steel gearing and the whole mounted on a heavy cast-iron base, which is bolted to the upper platform. The machinery is operated by either steam or gasoline power. The two swinging drums are operated by a double-cone friction and are connected to the drum shaft of the hoisting engine by a sprocket and bushed chain.

The distinctive feature of the machine is the guide boom, which consists of a steel girder shaped like a figure J, with the hook end hanging vertically from a straight boom. Both booms are pivoted at the front end of the upper platform. The bucket, which is a rectangu-



Jacobs Guided-drag-line-bucket Excavator.
Figure 55.

lar steel box, open at the end toward the machine, is attached to a trolley which travels on the guide boom, having two double-flanged wheels riding on the upper flange and a third wheel bearing against the lower flange to keep the bucket from kicking upward. "In making the cut, the bucket is hauled inward by a cable leading directly from the trolley to the engine. For dumping, it is hauled outward by the back haul cable, which leads from the trolley to the head of the main boom and back to the engine. The bucket is dumped by continuing its travel to the vertical end of the guide boom, the boom being first swung around to the position at which the load is to be deposited."

The machine is self-propelling and travels on a track, which is made in sections and is moved by the machine itself.

This machine has been used for the construction of open ditches, tile ditches and back filling same, levees, roads and highways, etc.

This excavator is built in various sizes, from one having a $\frac{3}{4}$-yd. bucket and 25-ft. boom to one with a $1\frac{1}{3}$-yd. bucket and a 40-ft. boom. The cost of the machines varies from $3,500 to $6,000, depending on the length of the boom and the capacity of the bucket.

A line drawing showing the construction of the Jacobs Guided-Drag-Line-Bucket-Excavator and the boom and bucket in digging and dumping positions, is given in Fig. 55.

46a. Use in Illinois.—At Dixon, Illinois, one of these machines constructed an open drainage ditch, having a 22-ft. bottom, a depth varying from 4 ft. to 6 ft. and $1\frac{1}{2}$ to 1 side slopes. The machine used had a 40-ft. boom, a $1\frac{1}{3}$-yd. bucket and was operated by a 7-in.×10-in. double cylinder, 3-drum hoisting engine, with swinging drums sprocket driven from the front drum of the hoisting engine. The weight of the machine was about 23 tons, which included one ton of coal and 300 gal. of water. The average excavation for a 10-hour day was 600 cu. yd. and the following table gives the cost of the work:

Operator,	$4.00
Fireman,	2.50
Trackman,	2.00
Coal,	5.00
Oil and Waste,	1.00
Water,	1.00
	$15.50
Add for interest, depreciation and repairs,	10.00
Total,	$25.50

For 600 cu. yd., this makes a cost of 4.25 cents per cubic yard.

During the month of December, 1911, an open ditch was constructed in DeWitt County, Illinois, by one of these Guided-Drag-Line-Bucket-Excavators. The ditch was 3 ft. wide on the bottom, with $1\frac{1}{2}$ to 1 side slopes, an average depth of 6 ft. and with 8-ft. berms. The material excavated was 4 ft. of gumbo and the substratum yellow clay. The yardage averaged 150 cu. yd. per station.

The labor employed consisted of an operator at $125 per month, a fireman at $2 per day, two trackmen at $1.75 per day and a cook at $40 per month. The men were furnished with free board and lodging. Following is a tabulated list of expenses:

Labor,	$117.62
Coal,	20.60
Coal hauling,	25.00
Repairs,	8.45
Camp supplies,	9.72
Cook's wages,	16.06
Traveling and livery,	32.55
Insurance,	7.14
Miscellaneous,	7.14
Total,	$234.28

NOTE.—Coal was hauled 8 miles from a railroad siding at a cost of 8 cents per hundred-weight and part of the time at a cost of $5 per load. The item of "camp supplies" does not include some supplies used, which were on hand and not purchased during the month. "Traveling and livery" include a special trip to inspect work and attend commissioners' meeting.

The work during the month comprised the excavation of $150\frac{1}{2}$ stations of 150 cu. yd. each and took $10\frac{1}{2}$ days. The average cost per day was $22.30, the cost per station $15.10 and the cost per cubic yard $0.10.

47. Locomotive Crane Excavator.[1]—A locomotive crane was used during April, 1910, in the excavation of a section of the New York State Barge Canal near Palmyra, New York. The crane was a standard Brownhoist crane with a boom having a length of 50 ft. and designed to carry at its end a load of 3 tons on a 48-ft. radius and with a counterweight of 12,000 lb. in the buck frame. The engine had a moving gear, a reversible swinging gear, and both drums are equipped with spur gears. The hoisting and drag line drums operated independently, the former having a diameter of 22 in. and controlled by a hand brake and friction clutch, while the latter had a diameter of 20 in. and was controlled by a foot brake. The power was furnished by a vertical boiler of the type shown in Fig. 43. The bucket used was a standard Page bucket of 1 cu. yd. capacity.

The material excavated was yellow clay for a depth of 5 ft. and underlaid by gravel and blue clay.

The ditch or canal had a top width of 60 ft., a bottom width of 20 ft. and a depth of cut varying from 9 to 10.5 ft. The total excavation made by the crane during 12 working days was 6,000 cu. yd. The labor organization comprised two crews, each working an eight-hour shift and made up as follows:

[1] From Article in Engineering-Contracting, May 10, 1911. Also see Chapter VIII.

1 engineer,	$100.00 per month.
1 fireman,	50.00 per month.
4 laborers,	1.60 per day.

The average cost of excavation was 9.5 cents per cubic yard.

48. Résumé.—Various forms of dry-land excavators have been devised and used, but some form of the scraper bucket or drag-line bucket machine is the most popular. This type of excavator is especially adapted to canal and ditch construction. It has the desirable method of operation by beginning at the outlet and working up-stream. Thus the ditch is completed as the dredge moves along over the solid earth at some distance ahead of the excavation. This will be noted in Fig. 54. This is of great importance when the soil is soft, loose or unstable.

The scraper-bucket excavator is an efficient machine for the excavation of canals and ditches where the amount of the work will be greater than 50,000 cu. yd. for one set up of the machine.

With careful operation, the side slopes of a ditch may be made quite uniform and smooth. The tendency is to make these side slopes too steep or steeper than 1 to 1. Unless the soil is a dense clay or other hard and firm material, the side slopes should never be steeper than 1 to 1. However, in some cases it is necessary to make the side slopes steeper, then the bottom width should be made large enough to allow for the gradual subsidence of the earth to the natural slope.

A scraper-bucket excavator has recently been used economically in coördination with a floating dipper dredge in the excavation of large ditches. The dry-land machine starts at the lower end of the ditch and works up-stream, excavating the upper section of the ditch. The floating dipper dredge commences at the upper end of the ditch and excavates all of the ditch at its smaller cross-sections and completes the lower section of the ditch at its lower end, where the cross-sections are large.

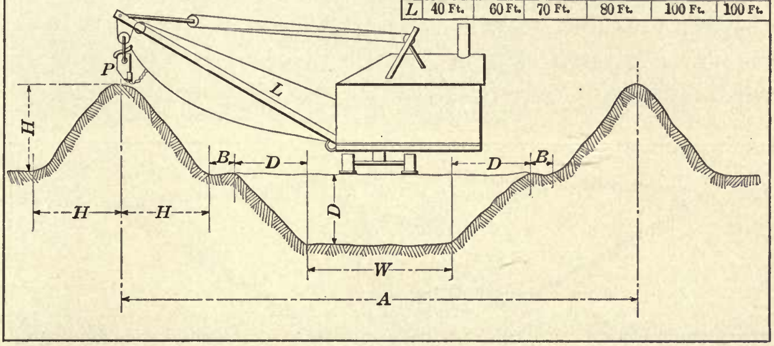
For the removal of sand, silt and loose gravel from natural streams or artificial channels, the excavator can work most efficiently with a long boom and a clam-shell or orange-peel bucket.

With the successful application of gasoline power to a scraper-bucket excavator, the fuel problem is considerably lightened for the use of a large machine at a distance from a railroad. The use of electric power is the ideal method of operation, when such power can be economically obtained from a local transmission line.

The amount of excavation which a scraper-bucket excavator

can accomplish depends on the size of the excavator, soil, climatic conditions, efficiency of operation, etc. Under average working conditions, in ordinary clay and loam, the output of a typical 2¼-yd. machine should average about 800 cu. yd. The operating cost should be from 4 to 6 cents per cubic yard. The limitations of six sizes of a standard make of scraper-bucket excavator are shown in Fig. 56.

	Type No.1	Type No.2	Type No.3	Type No.4	Type No.5	Type No.6
A	76′0″	128′0″	142′0″	168′0″	184′0″	198′0″
B	5′0″	8′0″	8′0″	10′0″	10′0″	10′0″
D	10′0″	12′0″	12′0″	14′0″	15′0″	15′0″
H	13′0″	20′0″	21′0″	25′0″	27′0″	29′0″
W	20′0″	50′0″	60′0″	70′0″	80′0″	90′0″
P	1 Cu. Yd.	2 Cu. Yd.	2¼ Cu. Yd.	2½ Cu. Yd.	2½ Cu. Yd.	3 Cu. Yd.
L	40 Ft.	60 Ft.	70 Ft.	80 Ft.	100 Ft.	100 Ft.



Limitations of Various Sizes of Drag-line Excavator.
Figure 56.

49. Bibliography.—For additional information, consult the following:

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1. The Chicago Main Drainage Channel, by C. S. Hill, published in 1896 by Engineering News Publishing Co., New York. 129 pages, 8 by 11 in., 105 figures.

2. Drainage of Irrigated Lands in the San Joaquin Valley, California, by Samuel Fortier and Victor McCone. Bulletin 217, published by Office of Experiment Stations, U. S. Department of Agriculture.

MAGAZINE ARTICLES

1. Ditching with the Bowman Ditcher, T. Ahern; Railway Age Gazette, August 18, 1911. Illustrated, 1,000 words.

2. The Dredging of the St. Lawrence River; Engineering-Contracting, November 4, 1908.

3. A Giant Excavator; Engineering, London, April 15, 1910. 2,000 words.

4. A Giant Steam Excavator; Scientific American, July 9, 1910. 2,000 words.

5. Large Bucket Boom Dredge; Engineering Record, July 27, 1895.

6. Method and Cost of Operating the Weeks Two-line Shovel for Drag-line

Excavators, Glenville A. Collins; Engineering-Contracting, April 26, 1911. Illustrated, 1,000 words.

7. A New Style of Scraper Excavator; Engineering News, March 2, 1905. Illuttrated, 600 words.

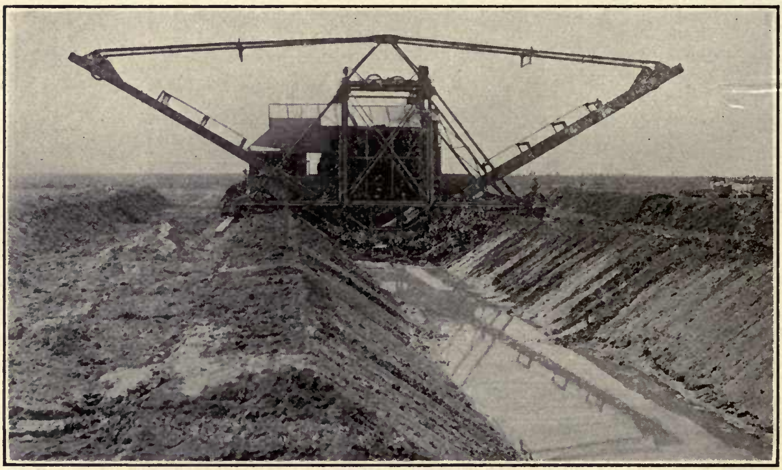
8. Scraper-bucket Excavator on New York State Barge Canal; Engineering-Contracting, March 23, 1910.

9. Some New Excavating Machines; Engineering News, March 16, 1911. Illustrated, 2,000 words.

10. Some Records of Work with a Scraper-bucket Excavator on the New York State Barge Canal; Engineering-Contracting, March 23, 1910. 1,000 words.

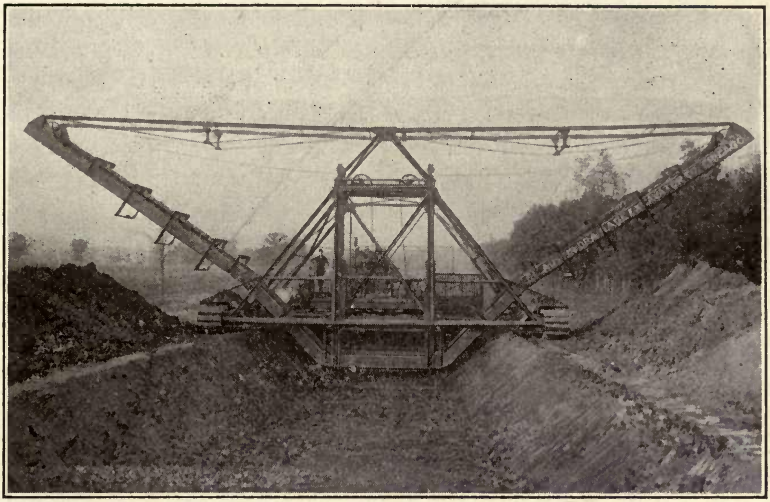
B. TEMPLET EXCAVATORS

50. Austin Drainage Excavators.—Many large, open ditches, which have been excavated with various forms of dredges, are very irregular as a result of steep side slopes, rough sides and bottoms, and the caving of banks. During the last few years, an excavator

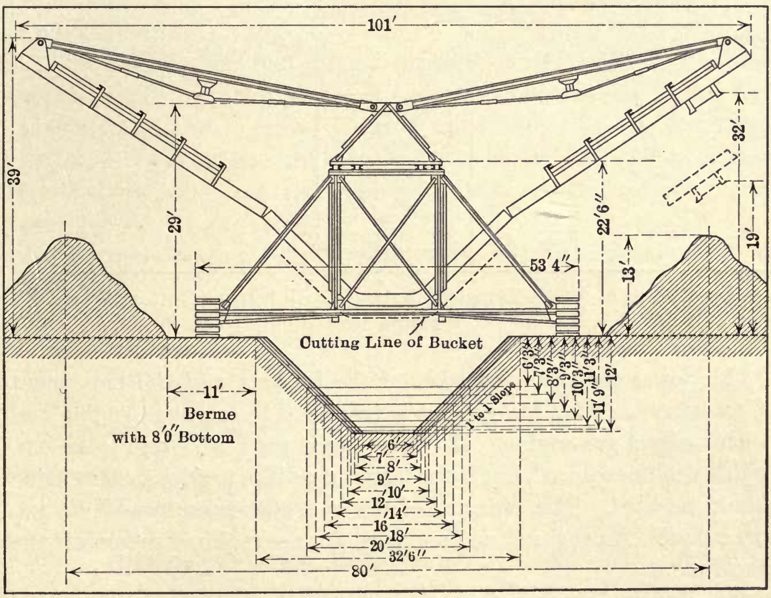


Austin Templet Excavator with Narrow Bottom Frame.
Figure 57.

has come into general use for the construction of open ditches with true and smooth side slopes and grades. This new, templet form of excavator is manufactured by the Austin Drainage Excavator Co. of Chicago. Two scrapers or buckets are connected together, facing in opposite directions (in the latest machine a single reversible positive cleaning bucket is used), and moved along a guide frame shaped to the desired cross-section of the ditch. This guide frame is supported

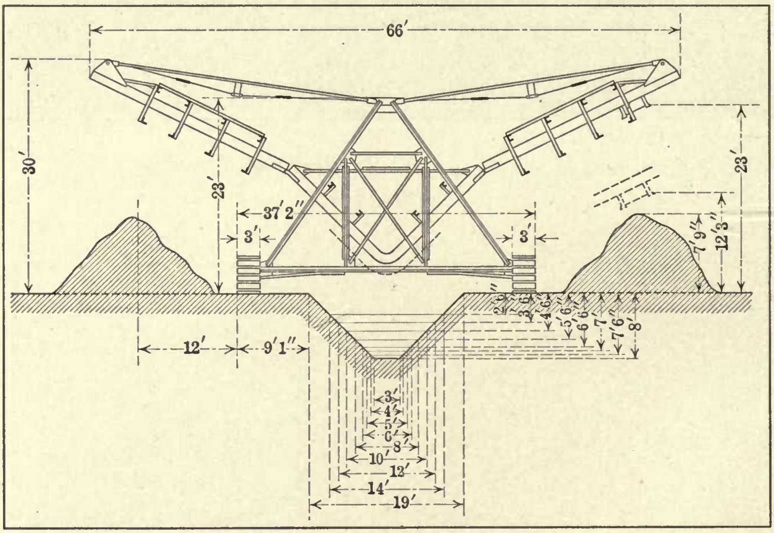


Austin Templet Excavator with Wide Bottom Frame.
Figure 58.



Limitations of Austin Templet Excavator with Wide Bottom Frame.
Figure 59.

on the front end of a large framework, which moves over the ground on four large caterpillar tractors. The ditch prism is gradually constructed by the excavation in thin layers of the earth, which the buckets carry to the outer ends of the frame, where the bottoms of the buckets are tripped and the contents dumped, either on spoil banks or into wagons. Two types of excavator are made, one with a pointed or narrow templet for the excavation of narrow bottom ditches, and the second with a broad templet for the excavation of wide bottom ditches. Figs. 57 and 58 show the two types of excavator in operation, and Figs. 59 and 60 give the dimensions and show the range of work for these machines.



Limitations of Austin Templet Excavator with Narrow Bottom Frame.
Figure 60.

The power for the propulsion of the buckets and the movement of the machine over the ground is furnished by a steam engine and boiler or by a gas engine. If the former is used, a 25-h.p. to 40-h.p. engine will be required, but if the latter, a 50-h.p. to 80-h.p. gas engine should be used. The capacity of the buckets varies from $\frac{1}{2}$ cu. yd. to 2 cu. yd. An engineer and one assistant are required to operate the machine.

50a. Use in Illinois.—One of these templet excavators was used in the construction of a drainage ditch in southern Illinois. The ditch had a bottom width of 4 ft., side slopes of $1\frac{1}{2}$ to 1, an average

depth of 6 ft., and a length of 10,600 ft. The total excavation was 29,704 cu. yd. and required 45 working days. The machine was dismantled, hauled 6 miles, and erected for this job, and the cost for this complete removal was $499.56. Following is a table of the operating expenses for this work, based on a cubic yard of excavated material.

Operating Expenses Per Cubic Yard

Superintendent,	$0.00250
Engineer and fireman,	0.01434
Moving track,	0.01575
Coal,	0.00880
Repairs,	0.00602
Board for entire crew,	0.00710
Explosives for stump removal,	0.00440
	$0.05891

The excavator was dismantled, hauled 4 miles and set up for the next job at a cost of $756.

The soil excavated was a sandy loam underlaid by a clay subsoil. The soil was heavy and wet but not swampy.

50b. Use in Colorado.—Two templet machines were used during the season of 1911 for the excavation of irrigation ditches in the San Luis Valley in Colorado.

The ditches excavated had 6- and 8-ft. bottom widths, an average depth of 6 ft. and side slopes of $1\frac{1}{2}$ to 1. The material varied from a sandy loam to a gravel stratum filled with silt. In the former material the average excavation was 750 cu. yd. for a 12-hour shift, while in the latter material the digging was hard and did not average over 500 cu. yd. per shift.

The following table gives the average cost of operation for a 12-hour shift.

1 operator,	$4.00
1 fireman,	3.00
1 trackman,	1.50
1 man and team on track,	4.25
1 man and team on water wagon,	4.25
1 cook,	1.00
Coal @ $4.50 per ton on cars,	6.00
Boarding supplies,	2.00
Oil,	1.00
Repairs, cable, chain, waste, etc.,	1.00
Total,	$28.00

At 750 cu. yd. for each 12-hour shift, the cost of operation would be 3.73 cents per cubic yard.

50c. Use in Texas.—During the years 1910 and 1911, an Austin templet excavator was used in the construction of drainage ditches in northeastern Texas. The soil excavated varied from a sandy loam to a dense mixture of yellow and blue clay. The ditches all had a uniform bottom width of 6 ft., the depth varying from 6 to 11 ft. and side slopes of 1 to 1. In loose, open soil, the average excavation per day of 10 hours was 1,000 cu. yd., while in dense, hard soil this amount was reduced to 500 cu. yd.

The cost of operation per day of 10 hours was as follows:

1 operatcr,	$4.00
1 engineer,	2.50
Supplies, repairs, etc.,	4.00
50 gallons gasoline @ 10 cents,	5.00
Total,	$15.50

The excavator worked very satisfactorily except in hard, dense, blue clay, which on account of being dry was in many places too hard to cut. The ditches, after two and three years service, have maintained true and uniform side slopes, with very little caving or shuffling off of banks.

51. Junkin Ditcher.—During the summer of 1906, an excavator, very similar in construction and method of operation to the Austin excavator, was used in Pembina County, North Dakota. This machine is known as the Junkin Ditcher, and consists of a steel-framed car, thoroughly braced and trussed. The sides of the car are supported on two trucks, each of which has four flanged steel wheels which run on a portable track laid on each side of and parallel to the ditch line. The car thus straddles the ditch and moves ahead parallel to it. On the car floor is placed the locomotive type boiler and the machinery, which consists of a double engine of 70 h.p. for operating the excavating machinery and a double engine of 30 h.p., for operating the cutting frame.

At the rear end of the car is placed a large triangular-shaped framework, the lower end of which is made like a templet to conform to the sides and bottom of the completed ditch. Around the perimeter of each half of this frame moves a bucket belt, composed of two chains 30 in. apart and carrying 14 steel buckets spaced at equal distances. These buckets have cutting edges which are bolted to the sides and can be easily removed for sharpening. The chains are driven toward each other and in opposite directions by means of cog gearing and move over large sheaves placed at the

vertices of the frame. The frame is fed downward by a screw gearing. As the bucket chains revolve, the buckets follow each other along the bottom of the excavation and then up the slopes, each one removing a thin slice of earth, which is carried to the top and outer end of the frame, where as the bucket turns about the sheave and starts on its return course, the earth falls out and the bucket is automatically cleaned by a stationary scraper. As the earth is excavated the frame is gradually lowered until the required depth is reached. This is shown by a graduated scale on the frame. Thus a strip of earth 30 in. wide is excavated to the finished grade line of the proposed ditch and the machine then moves ahead 30 in. and another strip 30 in. wide is excavated and so on until a section 30 ft. long has been dug. Then the machine is run back to the beginning of the section and the car is moved slowly ahead and the buckets remove the loose dirt and give the cross-section a final smoothing up. As the two bucket chains do not come together at the center of the bottom, a ridge is left in the completed ditch about 18 in. wide at the base, and 12 in. high, but this does not present a serious objection, as the flow of water in the ditch soon levels it. If desired, the ridge can be removed by moving the earth to one side by hand as the excavator proceeds on its first trip and this surplus material would be removed during the second passage of the excavator.

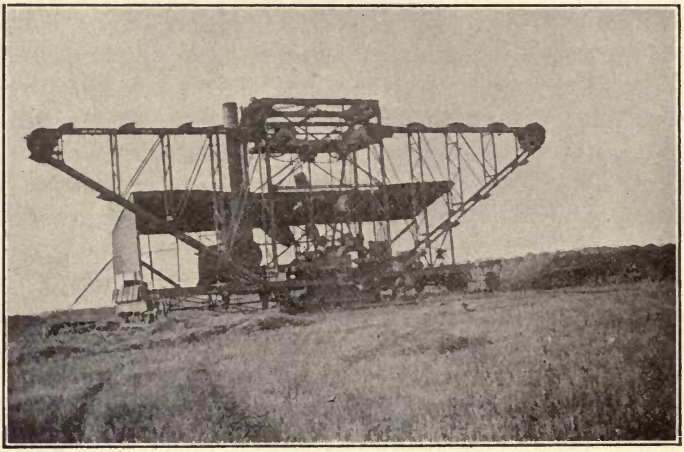
The track is made in 30-ft. sections, which are moved ahead of the machine by a team of horses, as fast as the sections of excavation are completed. The excavator starts at the outlet of a ditch and works up-stream, the excavating being done on the down-stream side of the car.

The labor required to operate a Junkin ditcher consists of one operator, who controls the operation of the excavator; one fireman and one oiler to feed the boiler and care for the machinery; a man and team for hauling water for the boiler and four men and a team to move the track.

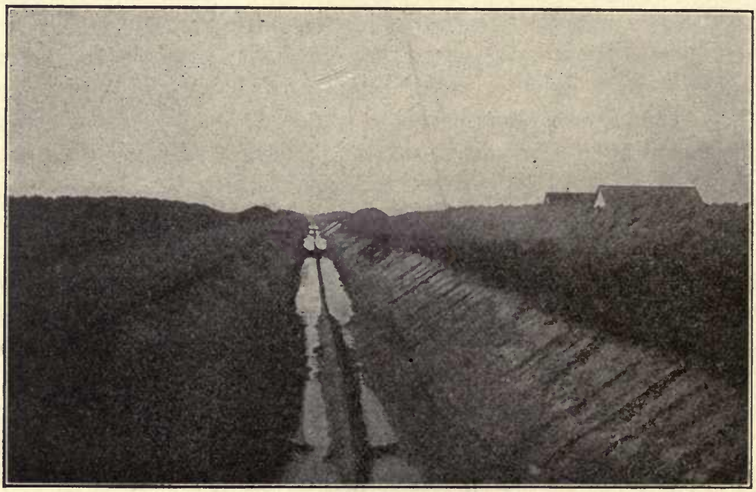
An average amount of fuel of two tons of coal is required to run the machine during a 14-hour working day.

The average excavation made by this machine during a 33 days' run of 14 hours per day, was 1,449 cu. yd. or about 100 cu. yd. per hour. The ditch excavated had a 10-ft. bottom, side slopes of $1\frac{1}{2}$ to 1 and a depth varying from 6 to 12 ft. A 5-ft. berm is left on either side of the ditch and the spoil banks have a triangular section and excavated material is deposited in them in a finely divided condition.

The excavator has a total weight of 60 tons and is made in sections so that it can be easily and readily assembled or dismantled.



Rear View of Junkin Ditcher.
Figure 61.



Ditch Excavated by Junkin Ditcher.
Figure 62.

The boiler is the only part of the machine which cannot be loaded on to an ordinary wagon. It is said that the dismantling and loading upon wagons can be accomplished by eight men in two and one-

half days and set up by the same crew in five days. Fig. 61 shows a rear view of a Junkin ditcher and Fig. 62 a ditch constructed by this machine.

52. Résumé.—A ditch should be excavated to a true grade and with uniform and smooth side slopes in order to ensure high working efficiency. Drainage and irrigation ditches are peculiarly susceptible to filling up with silt, débris and vegetation during seasons of low water. The author has seen very few ditches, whose capacity and efficiency, after three to five years of use, were not considerably reduced. In the case of small ditches this often becomes a serious matter, sometimes rendering the ditch practically useless. The only remedy in such a case is the re-excavation of the ditch. Large ditches generally require cleaning out every few years in order to maintain their efficiency and usefulness. In order to reduce this expense and trouble of maintenance to a minimum, ditches should be excavated as nearly mechanically true and uniform as is possible under existing conditions.

The templet excavator is the best form of excavating machine for the construction of an open ditch, when the soil conditions are favorable. Although this machine is beyond the experimental stage, its field of work is rather limited. It is not suited to the excavation of very wet land or where trees, stumps and stone abound. The recent machines are equipped with roller caterpillar traction and can work on soft soil by commencing at the outlet and working up-stream. Cases have come to the author's attention, where this machine has been unable to excavate dense clay and hard-pan. These defects of excessive weight and lack of power should be remedied in the near future by the manufacturers.

The templet excavator, in the excavation of the average firm soil of clay and loam, under average working conditions, has an average daily output of about 700 cu. yd. The operating cost will vary from 4 to 8 cents per cubic yard.

53. Bibliography.—For further information, the reader is referred to the following:

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1. The Chicago Main Drainage Channel, by C. S. Hill, published in 1896 by Engineering News Publishing Co., New York. 129 pages, 105 figures, 8 by 11 in.

2. Excavating Machinery by J. O. Wright. Bulletin published in 1904 by Department of Drainage Investigation of U. S. Department of Agriculture, Washington, D. C.

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1. A German Excavator on the New York State Barge Canal, Emile Low; Engineering Record, April 21, 1906. Illustrated, 700 words.

2. Lowrie's Power Excavator; Railroad Gazette, December 8, 1899. Illustrated, 1,300 words.

3. Mechanical Appliances for Canal Excavation, E. Leader Williams; Engineering News, October 31, 1891.

4. Methods of Excavating Canal Using a Bridge Conveyor Excavator, with Costs of Work for Twenty-four Consecutive Months; Engineering-Contracting, November 23, 1910. Illustrated, 1,800 words.

5. A New Canal Excavator; Railroad Gazette, September 25, 1891. Illustrated, 400 words.

6. The Van Buren Excavator; Iron Age, October 7, 1909. Illustrated, 1,500 words.

C. WHEEL EXCAVATORS

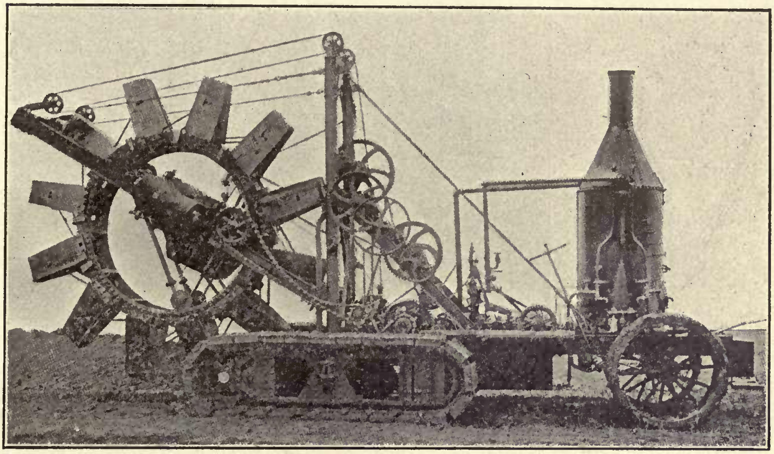
55. Field of Work.—Under this heading will be described machines used only for the construction of open ditches. The wheel machines of the trench excavator type will be described in Chapter VIII.

The wheel excavator is constructed so as to make a trench or open ditch with sloping sides at a continuous cut. It is especially useful in the construction of lateral ditches for the drainage of wet prairie lands.

56. Buckeye Traction Ditcher.—Fig. 63 shows a typical wheel excavator, which is made by the Buckeye Traction Ditcher Co., of Findlay, Ohio. As will be seen from the illustration, the ditcher consists of a frame, which supports an engine on the front end and on the rear end a pivoted framework containing an excavating wheel. This is an open wheel which revolves upon anti-friction wheels placed just outside the rim of the wheel. Around the circumference of the wheel are 12 open buckets, open front and back and with continuous, closed sides. The front edge of each bucket is provided with a cutting edge, which removes a slice of earth in the revolution of the wheel. When a bucket reaches the top of the wheel, the earth falls out of the bucket upon a belt conveyor. This conveyor or carrier can be set to carry the earth outside of the ditch to the spoil bank on either side. Where loose, sandy or gravelly soil is encountered, it is necessary to use solid buckets. One of the special features of this machine is the use of Apron or Caterpillar Tractions, which spread the weight of the machine over a large area and allow the machine to travel over wet soil, which would support a team of horses and an empty wagon. This machine is built in several sizes, so that ditches may

be excavated having top widths from $2\frac{1}{2}$ ft. to 12 ft. and side slopes of any reasonable amount. The excavator shown in Fig. 63 weighs 15 tons and costs $5,200 f.o.b. factory.

57. **Austin Wheel Ditcher.**—The Austin Wheel Ditcher, manufactured by the F. C. Austin Drainage Excavator Co., of Chicago, is another well-known make of this type of excavator. Fig. 65 shows



Wheel Excavator.
Figure 63.

one of these machines excavating an open ditch. The essential parts of this excavator are the same as those of the Buckeye; the main difference being in the construction of the excavating wheel. In this machine the wheel frame supports a central shaft about which the wheel revolves. The bottom width is cut directly by a series of self-cleansing buckets, which are placed on the circumference of the wheel. The side or lateral supports of the wheel have cutting edges and make the side slopes of the ditch. The following table gives the capacity, weight, cost, etc., of the two different sizes of this excavator.

These machines are all convertible, so that by removing the side supports, the bank sloping attachment is eliminated and the machine becomes a trench excavator. The machines are built of steel throughout, special alloy steel being used for the gears, the wearing parts such as the bushings and pins of the excavator chain, the links of the caterpillar tractions, and the cutting edges of the buckets are of manganese steel.

TABLE XVIII.

SPECIFICATIONS OF AUSTIN WHEEL DITCHER

Size No.	Horsepower		Max. depth	Width of cuts[1]		Traction speed per hour	Delivering dirt	Height of machine[2]	Approximate gross weight.
	Steam	Gasoline							
No. 00 with bank sloping attachment.	12	24	5 ft.	90 in.	Any slope up to 1 to 1.	$1\frac{1}{2}$ miles	Either side	11 ft.	29,000 lbs.
No. 0 with bank sloping attachment.	20	40	6 ft.	10 ft.				11 ft.	39,000 lbs.

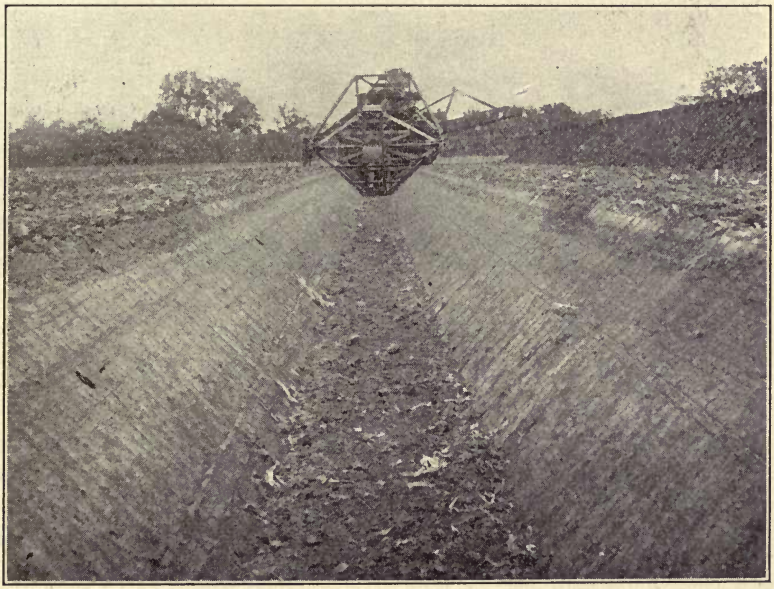
[1] NOTE.—The digging cuts are the widths of the buckets only. Buckets should never be used without side cutters except in very soft ground. Side-cutters will increase the width of cut from $1\frac{1}{2}$ to 4 in.

[2] NOTE.—We give only approximate figures on width, height and weight. Different equipments change these figures.

The ditchers are generally equipped with caterpillar tractions for the two rear wheels. These moving, endless platforms distribute the weight of the machine over a large area and thus enable the machine to move over soft ground. The sizes of caterpillar tractions used are given in the following table.

Size of machine	Size of caterpillar traction
00	4 ft. wide by 6 ft. long.
0	4½ ft. wide by 11 ft. long.

It has generally been found more economical to use a gasoline engine instead of steam-power for the operation of these ditchers. Gasoline is cheaper and easier to handle than coal and the cost of



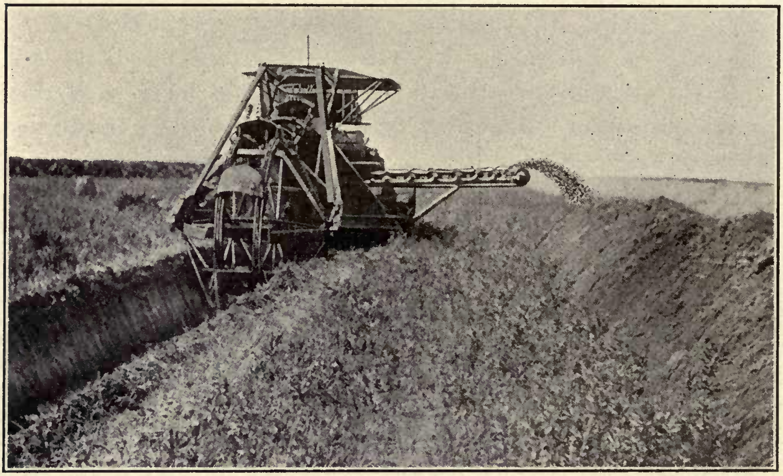
Wheel Ditcher operating under Gasoline Power.
Figure 64.

the developed horse-power is less with the former type of fuel than with the latter. A gasoline engine takes up less space, is easier and cleaner to operate than a steam boiler and engine. A No. 00 size

ditcher requires a 24-h.p. gasoline engine and a No. 0 size ditcher a 40-h.p. engine.

The average yardage, for one of these excavators, is about 300 cu. yd. per 10-hour day, in the excavation of a ditch in ordinary soil of loam and clay. Under favorable conditions of soil, climate and operation, a maximum yardage of 500 cu. yd. has been made.

Figure 64 shows a No. 0 machine equipped with a four-cylinder, 40-h.p. gasoline engine starting the excavation of a ditch with a bottom width of 3 ft. and a maximum depth of 5 ft.



Wheel Excavator Constructing Small Ditch.
Figure 65.

Figure 65 shows a No. 00 ditcher excavating a ditch with a bottom width of 2 ft. and an average depth of 4 ft. This view clearly illustrates the smooth side slopes and true grade of the ditch and shows the spoil bank neatly made at one side of the ditch and with a clean berm between it and the edge of the ditch.

58. Résumé.—The wheel excavator is the most practical machine for the excavation of small open ditches. In irrigation and drainage systems, where the laterals and distributaries run full only during a small part of each year, a large amount of silt, débris and vegetation generally accumulates. These obstructions will in a few years, unless removed, greatly impair the efficiency of the channel. Hence,

it is necessary that these smaller ditches especially should be excavated to a true grade and with smooth, uniform side slopes.

Irrigation ditches are often lined with some impervious material such as concrete to prevent seepage losses. It is a great advantage in such a case to have the ditch excavated to true grade and side slopes so that the forms for the concrete lining may be set without the expense and extra labor of trimming and shaping the excavation.

The belt conveyor of the wheel excavator removes the excavated material to a considerable distance from the edge of the ditch, leaving a clean berm. It is important that the spoil banks should be far enough from the edges of the ditch to prevent caving and the washing back of the excavated material into the ditch.

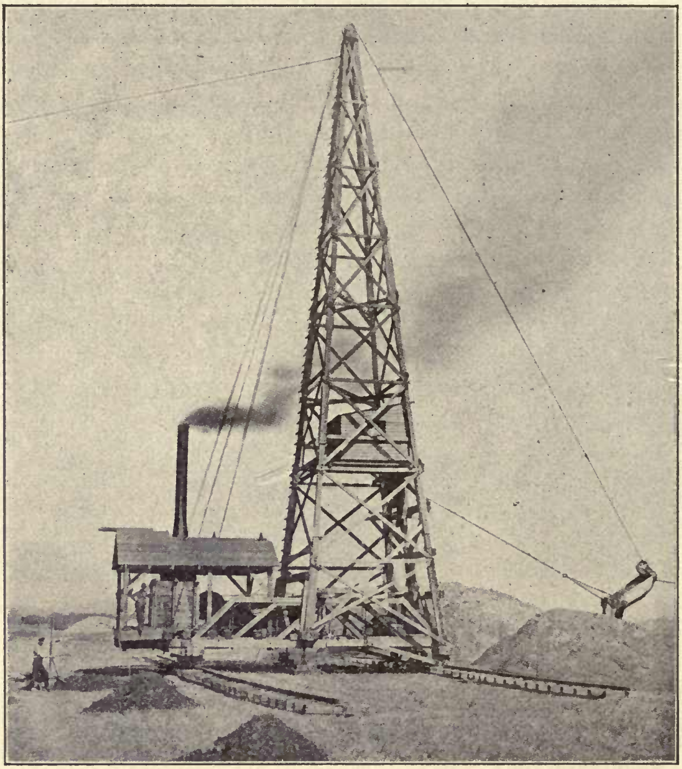
As regards the capacity and operating cost of a wheel excavator, the following estimate is based on recent experience in drainage ditch excavation in the South. Let us assume an average size of machine which digs a ditch having a top width of 4 ft. 6 in., average depth of 3 ft. 6 in., bottom width rounded to 12 in. and side slopes of about $\frac{1}{2}$ to 1. Average soil and working conditions are considered.

Labor:	Per day	
1 operator, @ $125 per month,	$5.00	
1 assistant operator,	2.50	
4 laborers, @ $2,	8.00	
Total labor cost,		$15.50
Fuel:		
20 gal. of gasoline @ $0.16,		4.80
Miscellaneous:	Per day	
Oil, waste, etc.,	$0.60	
Repairs and maintenance,	5.00	
Interest, 6 per cent. of $6,000,	2.00	
Depreciation, 150 working days a year, for eight-year life,	5.00	
Total miscellaneous,		$12.60
Total operating cost per day,		$32.90
Average progress per day,		2,500 ft.
Average daily excavation,		870 cu. yd.
Average cost of excavation, $32.90÷870		$0.038 per cubic yard.

D. TOWER EXCAVATORS

62. Single Tower Excavator.—A type of drag-line excavator which was used with success several years ago on the Chicago Drainage Canal and recently on the construction of the New York State Barge Canal, is the Tower Excavator.

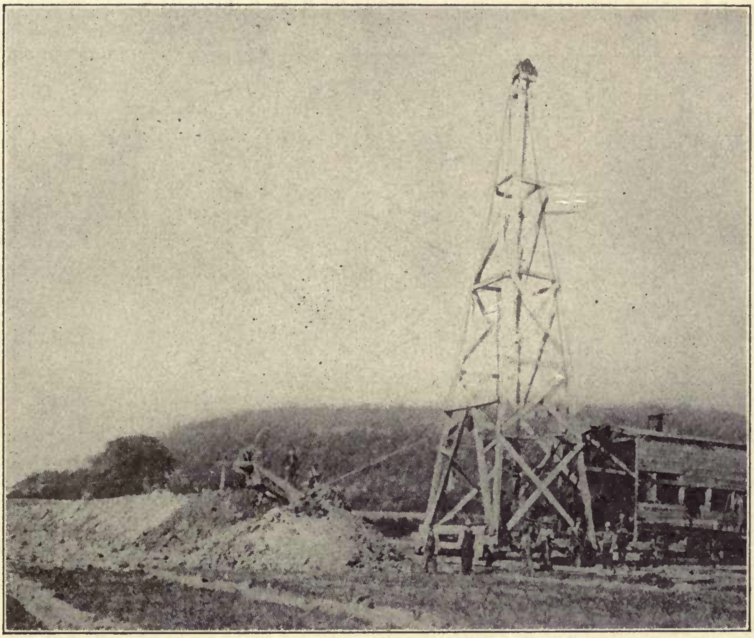
As shown by Figs. 66 and 67 the excavator derives its name from



Tower Excavator.
Figure 66.

its principal part, which is a movable tower. The latter is a framed timber structure, the height of which is determined by the width of the ditch or canal to be excavated. The height varies from 50 to 85 ft., with an average height of 75 ft. The tower rests on a platform or car which is trussed by overhead, horizontal, chord, combination trusses. The car is mounted on four solid double-

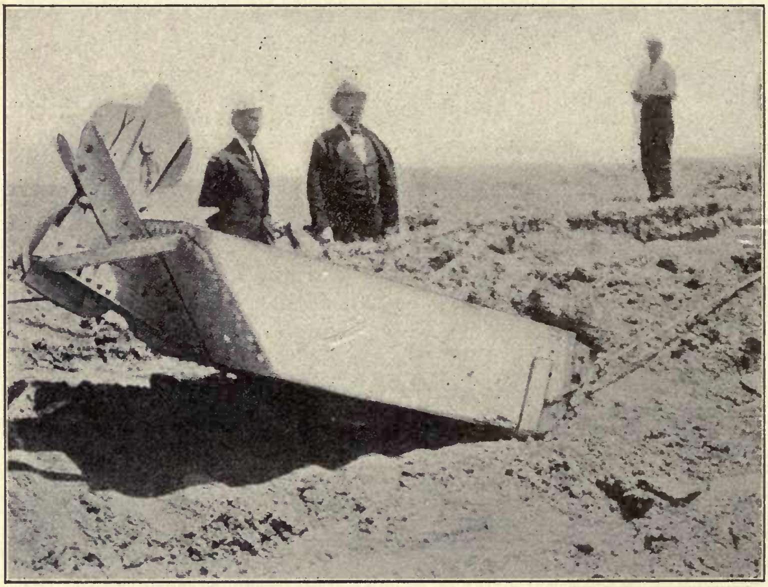
flange cast steel wheels, generally about 14 to 16 in. in diameter, and with 4-in. treads. The wheels run on a track, which consists of 80- to 90-lb. rails, spiked to cross ties, bolted to 30-ft. planks. The car and tower are moved ahead by a cable which passes over a sheave on the car and to a "dead-man" placed at a suitable point ahead of the car, and then back to a "nigger head" on the engine. The track section is moved ahead in a similar manner. The tower is braced to the car by cables which extend from the top of the tower to the rear end corners of the car.



Tower Excavator.
Figure 67.

On the rear end of the car is placed the power equipment, which consists of a vertical boiler and a double drum, 10×12-in. vertical engine with two "nigger heads." The machinery in the best plants is operated by a man stationed on a platform placed on the rear side of the tower about one-third of its height. The operator controls the excavator by suitable levers and brakes, and he has an unobstructed view of the work.

The bucket used as is shown in Fig. 68, is a two-line scraper bucket with peculiar features. At the rear of the bucket is a frame carrying two sheaves at right angles to the cutting edge, which is strongly reinforced. On the bottom of the bucket are two curved shims or shoes. The front of the bucket is connected to the drag-line drum of the engine by a cable which passes over a sheave suspended on the front side of the tower about one-fourth to one-third of its height. Another cable extends from the hoisting drum of the engine over a sheave at the top of the tower, then between the sheaves fastened to the bail of the bucket and then fastened to an anchorage at the other side of the ditch. The bucket is loaded by pulling it



Scraper Bucket of Tower Excavator.
Figure 68.

toward the tower by winding up the drag-line cable. When the spoil bank is reached, the hoisting cable is raised and the bucket is overturned and dumped. The bucket is returned to the ditch by still further tightening the hoisting cable and releasing the drag-line cable, whereby the bucket rises and slides back to the starting-point. Where a tower 65 ft. high has been used, a reach of 210 ft. from the far side of the ditch to the near side of the spoil bank was used with efficiency of operation. A scraper bucket of 2 cu. yd.

has an average carrying capacity of 3 cu. yd. and has been operated at the rate of 4 cu. yd. a minute. Under favorable conditions in the excavation of loam and clay, 2,000 cu. yd. have been excavated during a 10-hour shift and where two shifts have been used per day, an average monthly excavation of 40,000 cu. yd. has been made.

The following table gives the cost of operation of the tower drag-scraper excavator under normal conditions for a 10-hour shift.

1 engineer,	\$3.50
1 fireman,	2.50
1 foreman,	4.00
1 signal man,	2.00
1 cable shifter,	1.75
4 laborers, @ \$1.75,	7.00
2 tons of coal @ \$3	6.00
Maintenance, repairs, etc.,	0.75
Depreciation, interest on investment, etc.,	2.00
Total cost of operation,	\$29.50

The cost of a complete tower excavator would be about \$2,000.

62a. Use on New York State Barge Canal.[1]—The following is a detailed estimate of the cost of a tower excavator, which has recently (1910–12) been used on the New York State Barge Canal.

5,080 ft. B. M. lumber @ \$38 per M,	\$ 193.04
360 ft. B. M. white oak @ \$45 per M,	16.20
540 lb. iron bolts and nuts @ 6 cents,	32.40
120 ft. $\frac{5}{8}$-in. wire rope backstays,	13.20
2 $\frac{5}{8}$-in. turnbuckles,	.80
1 headblock sheave and bearing,	10.00
1 hauling sheave and bearing,	4.00
1 $8\frac{1}{4}\times10$-in. Lidgerwood double-drum hoisting engine,	1,089.00
1 scraper bucket, complete with cutting edge, sheaves, etc.,	300.00
Labor erection (carpenters @ \$2.50 for eight-hour day),	200.00
Total,	\$1,858.64

At a cost of operation for a two-shift day of \$60 and with an average daily excavation of 2,000 cu. yd., the cost of operation per cubic yard would be 3 cents.

During April, 1910, a tower excavator[2] was used on Contract

[1] Engineering-Contracting, October 26, 1910.

[2] Engineering-Contracting, Sept. 28, 1910.

No. 42 of the New York State Barge Canal. The material excavated consisted mostly of a heavy gumbo soil. The tower was 85 ft. high and the bucket used had a capacity of $1\frac{7}{8}$ cu. yd. The excavator was operated by a 10×12-in. hoisting engine, which was furnished steam from a 40-h.p. boiler. Following is a tabulated statement of the cost of labor and excavation.

1 operator, per day,	$4.00
1 fireman @ $75 per month, per day,	2.50
1 foreman @ $200 per month, per day,	6.67
1 pumpman, per day,	1.50
6 laborers @ $1.50 per day,	9.00
Total cost of labor per day,	$23.67
Total cost,	$1,455.81
Total cubic yards excavated,	15,065
Cost per cubic yard,	$0.096

Although this type of excavator has been rarely used and is little known and understood by contractors, its use in the past has clearly demonstrated its efficiency and economy of operation, especially in the excavation of large ditches.

During the early part of the year 1910, a tower excavator was at work on a section of the New York State Barge Canal. The following statement of the cost of operation has been furnished by the contractors:

Labor:

1 fireman @ $37\frac{1}{2}$ cents per hour,	$3.00	
1 engineer @ $37\frac{1}{2}$ cents per hour,	3.00	
1 fireman @ 22 cents per hour,	1.76	
1 signal man @ 25 cents per hour,	2.00	
9 laborers @ 20 cents per hour,	14.40	
Total cots of labor per shift,	$24.16	
Total cost of labor per month (52 shifts),		$1256.32

Material:

Wire cable,	$160.00	
Fuel, 20 tons of coal @ $4,	80.00	
Oil, waste and repairs,	15.00	
Total cost per month,		$255.00
Interest on investment $\frac{1}{2}$ per cent. per month,		9.30

Total cost of operation (not including office expenses),	$1520.62
Total excavation @ 700 cu. yd. per day,	18,200
Cost of excavation per cubic yard; $1520.62÷18,200=	$0.084

63. **Double Tower Excavator.**—A double tower drag-line excavator was used with very satisfactory results in the excavation of two sections of the Chicago Drainage Canal. The canal prism, which this excavator made was unusually true to the theoretical cross-

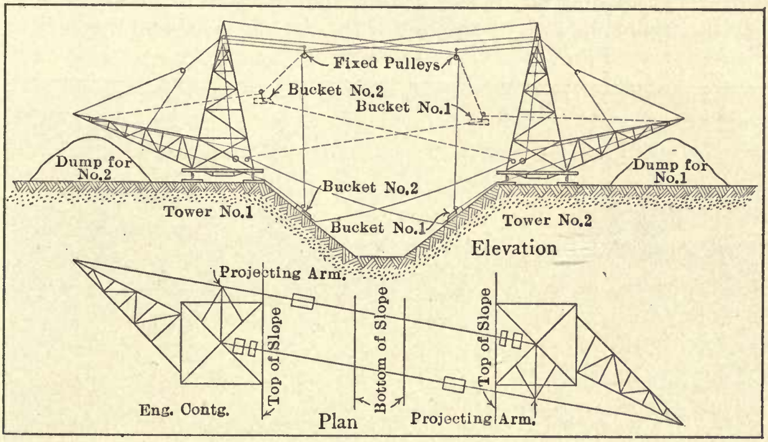


Diagram of Double Tower Excavator.
Figure 69.

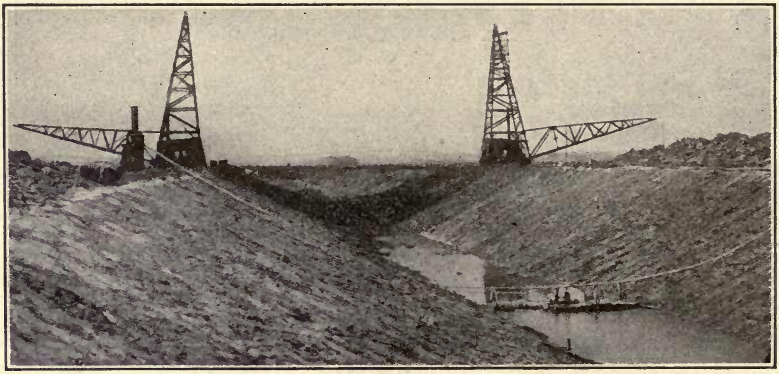
section, there being less than 1½ cu. yd. of excavation per lineal foot outside of the required lines.

The canal excavated had a bottom width of 26 ft. and side slopes of 2 to 1. The average depth was 27½ ft. The canal lay in nearly a level plain and the material excavated was clay.

This excavator was designed by the late J. T. Fanning of Chicago, and consisted principally of two towers and two buckets. Fig. 69 is a diagram illustrating the principles of construction and operation. It will be shown by the plan that the two inclined booms are so constructed that a straight line from the apex of either tower to the point of the opposite boom, clears the side of the tower. This allows the bucket to clear the tower and empty directly on the adjacent spoil bank. As will be seen from Fig. 69, there are two buckets, working in opposite directions and each excavating its half of the canal prism.

A double-drum hoisting engine was placed on the side of the platform of each tower. Each bucket was operated by a drag or digging

line and a load line. The drag line was run from the smaller drum of the engine to the bucket, which dug in a downward direction on the side of the canal opposite to its tower. The load line, which is slack during the filling of the bucket, extends from the larger drum of the engine, upward through the tower, over a sheave near the apex of the tower, then out to a stationary sheave, which is suspended between the two towers, then down to a sheave attached to the bail of the bucket and then out to the end of the boom on the opposite tower. As soon as the bucket is filled the load line is wound up with the drag line kept taut. This raises the bucket up above the surface



Double Tower Excavator.
Figure 70.

of the ground and to an elevation slightly higher than the point of the boom. Then the drag line is released and the bucket allowed to run down the load line by gravity to the dump pile or spoil bank near the end of the boom. By changing the location of the suspended sheaves, the position of the bucket in digging can be altered so as to reach the entire half width of the canal prism.

The buckets used had a capacity of $\frac{3}{4}$ cu. yd. and a tripping device near the end of each boom, caused the bottom of each bucket to swing loose and drop the load on the spoil bank.

The excavator was used for a period of two years on daily shifts of 10 hours. The labor employed consisted of an engineer, a fireman and a track gang of five men. An average gang of 12 men, including a superintendent, a watchman and the operating laborers, were used. The average daily excavation was 500 to 600 cu. yd. The maximum monthly excavation was 19,000 cu. yd. in June,

1910, while the minimum monthly excavation was 4,750 cu. yd. in December, 1908. A record of two trips per minute for each bucket was made but the average speed of excavation was one trip per minute.

64. **Résumé.**—The tower excavator is a type which was developed about 20 years ago during the construction of the Chicago Drainage Canal. The original machine had one tower and bucket, while the later examples use two towers and buckets.

This novel excavator has been used with great success upon the Chicago Drainage Canal and the New York State Barge Canal. The field for such a machine is a large canal, where the material is of the class that can be economically handled by a scraper bucket. Very soft and wet soil or rock could not be successfully handled. There are often wide irrigation and drainage canals constructed by the use of other excavators with considerable difficulty and delay, which could be built to great economic advantage with the tower excavator. For a ditch with a top width of over 60 ft., it is generally necessary to use dry-land excavators in pairs, one on each bank, or a large floating dredge which must move from one side of the canal to the other. With the tower excavator, a canal of any practical width can be excavated by one machine at one set-up and completed as the machine advances.

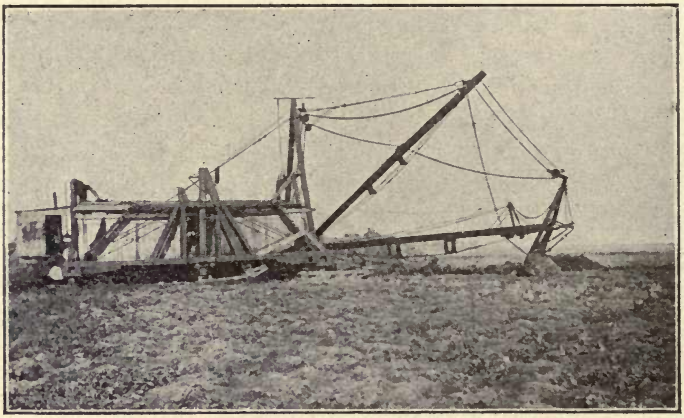
E. WALKING DREDGES

68. **Field of Work.**—In construction work on drainage and irrigation projects it is often the case that several ditches are to be excavated in the same locality. When the excavator is through with one ditch and wishes to start in on another ditch, it is often necessary to dismantle the excavator, transport the parts to the new site and assemble them. This often entails an expenditure of considerable time and labor. To provide an excavator which would move itself over ordinary country from one job to another, the walking dredge was devised. The first machine of which the author has knowledge was constructed about 10 years ago by A. N. Cross of Tomah, Wisconsin, and since that time a large number of these dredges have been constructed and used, especially on drainage work in Minnesota, Iowa and Nebraska.

69. **Description of Dredge.**—The walking dredge consists of a wooden hull, constructed of heavy timbers, and braced along the sides by large, overhead, wooden trusses. The hull is made of sufficient

width to straddle the ditch as it is being excavated. On the front of the hull is placed the A-frame, which generally is composed of two heavy timbers bolted to the sides of the hull at their lower ends with their upper ends meeting in a "head" casting. The A-frame is set in a vertical plane and braced by wire cables, which extend from the top of the frame to the rear of the hull. Fig. 71 gives a side view of a dredge showing truss and A-frame in detail.

On the floor of the hull is placed the boiler and machinery. When steam-power is used the equipment is very similar to that used on a floating-dipper dredge; the boiler being placed on the rear end and

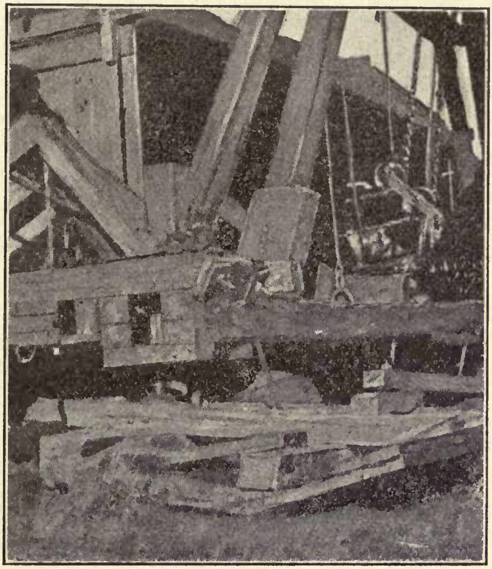


Side View of Walking Dredge.
Figure 71.

in front are placed the hoisting and swinging engines. On account of the expense of getting coal, where the work is a long distance from a railroad, it has been found more economical to use a gasoline engine to furnish the power. Engines from 16 to 50 h.p. are used, depending on the capacity of the machine, the size of the ditch and the character of the soil. A machine with a 40-ft. boom and a $1\frac{3}{4}$-yd. dipper has been satisfactorily worked with a 50-h.p. gasoline engine.

The excavator is supported at each of its front corners by a timber platform constructed like a stone boat and called a foot. Each foot is 6 ft. wide, 8 ft. long and 4 in. thick and an iron bar fastened to the bottom near the front edge prevents slipping. Each pair of feet is joined transversely by a light timber, so that both will move conjointly and in the same direction. Each foot is pivoted to the hull and connected to a drum by a chain, so that by revolving the

drum, the direction of the feet may be changed by the operator. In the center of each side or midway between the corner feet, is a center foot, similar in construction to the corner feet but having a length of 14 ft. and a width of 6 ft. On the under side of each center foot, a 6×6-in. timber is fastened transversely to prevent slipping. A large timber extends from the top of each center foot, between each pair of trusses, where it is pivoted. A chain, one end of which is fastened to the side timbers of the hull, passes over two pulleys attached to the frame on which the foot support is pivoted, and then

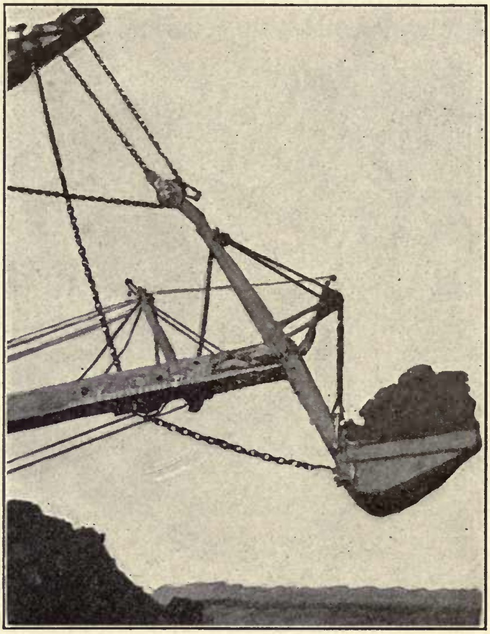


Corner Foot of Walking Dredge.
Figure 72.

passes along the hull to the rear corner and across the back end to a drum near the center of the hull. To move the machine the drum is revolved and the winding up of the chain pulls the foot support gradually to a vertical position. This raises the dredge from the corner feet and it moves ahead about 6 ft. The rear chain is then released and the weight is taken off of the center foot, which is pulled ahead by a chain attached to a drum, located near the center of the front part of the hull. Fig. 72 shows a detail view of a corner foot.

The boom is made up of two parts, the upper part is supported at its lower end on a turntable similar to those used on a floating-

dipper dredge. The upper end is supported by a cable from the peak of the A-frame. The lower part of the boom is pivoted at one end to the lower end of the upper section and on its outer end is pivoted an iron-trussed framework shaped like a walking beam. A chain or wire cable passes from the upper end of this frame to a drum on the hull. By the winding up of this chain or cable, the top of the frame may be pulled back. To the lower end of the frame is fastened



Dipper and Dipper-arm of Walking Dredge.
Figure 73.

the dipper which is shaped like the pan of a slip scraper. A chain or cable is also fastened to the frame at the back of the scoop. This line passes over pulleys in the outer ends of the booms and then to a drum on the hull. By the winding up of this line the scoop is pulled back and tilted to a vertical position. Fig. 74 will clearly show the details of the boom and scoop. To excavate, the lower section of the boom is lowered until the tip of the scoop is at the required level; the line attached to the upper end of the walking beam is then wound up and the scoop is thus forced forward into the earth. After the scoop is filled the lower section of the boom is raised and at the

same time swung to one side until the scoop is over the spoil bank, where the upper line is released and the lower line is pulled in until the scoop is drawn back to the boom and the contents of the scoop are dumped.

The machine can move ahead, across country at the rate of one mile in about 10 hours. It can make a quarter turn in about 50 ft. In very soft swampy land the machine can be operated by placing a large pontoon under the hull to float the machine and support the larger part of its weight. It may be operated as a rear or head-on excavator. In the first case, the machine starts at the outlet and backs up away from the excavation like a drag-line excavator, while in the latter case, the machine starts at the upper end of the ditch and straddles it as it excavates.

70. Operation of Dredge.—In the Spring of 1907, a walking dredge operated in the Red River Valley near Stephens, Minnesota. The boom was 40 ft. long and supported a $1\frac{3}{4}$-yd. scoop. Power was furnished by a 50-h.p. gasoline engine. The machine was operated in two shifts of 11 hours each, and each shift consisted of an operator, a craneman and a shoveler. One foreman had general charge of the work and a team and driver did the hauling. An electric motor furnished current for the night shift.

The ditch excavated had a bottom width of 6 ft., an average depth of 5 ft. and side slopes of $1\frac{1}{2}$ to 1. The soil excavated was a heavy sandy loam underlaid with yellow clay. The average daily progress made was 400 ft. per shift, or 2,000 cu. yd. per 22-hour working day. The average amount of fuel used was 75 gal. of gasoline. The ditch was excavated by the head-on method of moving down-stream and straddling.

70a. Use in Minnesota.—On a ditch in Minnesota, with a 9-ft. bottom width, an average depth of 9 ft. and 1 to 1 slopes, where the soil was very soft loam and peat, the contractor reported an average excavation of 3,000 cu. yd. for two shifts of 11 hours each. A record was made of 3,000 cu. yd. during one 11-hour shift.

70b. Use in Nebraska.—A walking dredge has recently (1911) been used with great efficiency in the excavation of a small ditch in eastern Nebraska. The dredge was of the usual type and equipped with a $1\frac{1}{2}$ cu. yd. dipper and power furnished by a 40-h.p. gasoline engine. The material excavated was a surface soil of gumbo, underlaid with soft yellow clay. The ditch had a bottom width of from 6 to 8 ft. a depth varying from 6 to 9 ft. and side slopes of $1\frac{1}{2}$ to 1. The average excavation was 50,000 cu. yd. per month.

A new type of walking dredge has recently (1911) been devised for use in the excavation of a small ditch in western Iowa.[1]

A drag-line excavator is mounted on its turntable, which is supported by a platform composed of steel I-beams. This lower platform has a length equal to twice the width of the turntable platform and the two are arranged so that the upper platform will roll upon the lower. The whole structure is supported on two skids, shaped like scows with flat bottoms. To move ahead the machine is rolled over to one end of the lower platform where its weight rests on one skid. The other skid is then slipped ahead by cables operated from the main engine. The machine is rolled to the other end of the platform thus placing the weight over the second skid, and the first skid is pulled ahead. Thus a zigzag forward motion is made with an advance of about 7 ft. at each skid shove.

The excavator was equipped with a 2 cu. yd. Page bucket, a 60-ft. steel boom and a 60-h.p. gasoline engine. An observation of the machine in operation during a short period of time, showed that nine buckets of material were excavated and the machine moved ahead about 7 ft. every eight minutes.

The excavator was operated by one man with an assistant as a general laborer. The ordinary track gang is thus done away with.

The experience of the contractor with this device indicated that it eliminates the slipping which ordinarily occurs when a drag-line excavator is mounted on rollers and the latter become wet.

71. Résumé.—The walking dredge is rather a novelty in the field of excavating machinery, but has already achieved some excellent records for economical operation. Every case of its use, of which information has been secured, shows a fairly large output at a comparatively low cost. While working on one large drainage project in the Middle West, a walking dredge made a better record than a dipper dredge operating on the same work and under similar conditions.

This unique dredge has the advantage over the ordinary dry-land or floating dredge, in being able to move over the country, from one job to another, by means of its own power.

[1] From Engineering-Contracting, July 19, 1911.

CHAPTER VII

FLOATING EXCAVATORS

75. Classification.—The dredges of this class, as the name signifies, move along a stream like a boat. They are classified as to the methods used in excavating the material, as follows: A, Dipper dredges; B, ladder dredges; and C, hydraulic dredges.

A. DIPPER DREDGES

76. General Description.—The type of dredge which is best known and commonly used for the excavation of drainage ditches is the floating-dipper dredge. The principal parts of a dipper dredge are the hull or boat, the power equipment, the hoisting engines, the swinging engines, A-frame, spuds, boom and dipper. All of these parts are used in some form in every dredge. Each manufacturer uses the same principles of operation, but varies the details of construction to suit his ideas and generally claims therefor certain points of superiority. Fig. 75 shows the principal parts of a floating-dipper dredge with vertical spuds and Fig. 76 those of a dredge with bank spuds. It is the general custom to set up the machinery of each dredge complete on the testing floor of a factory and to give it a thorough test before it is shipped to the purchaser. This test is of value in so far as it assembles all of the parts and proves their ability to work in coördination up to certain standard requirements. However, as such a test is conducted under the most favorable conditions, with good fuel, pure water, stable foundations, light and uniformly applied loads, it does not show how the machinery will stand up under the actual conditions of low-grade fuel, impure water, unstable foundations, and vibratory and repeated loads. The only satisfactory method to become acquainted with the weak as well as the strong points of any piece of machinery is to give it a severe test or series of tests under actual working conditions.

Hull

The hull or boat is generally built of wood and of such dimensions as the size of the machinery, length of boom, size of dipper, and the

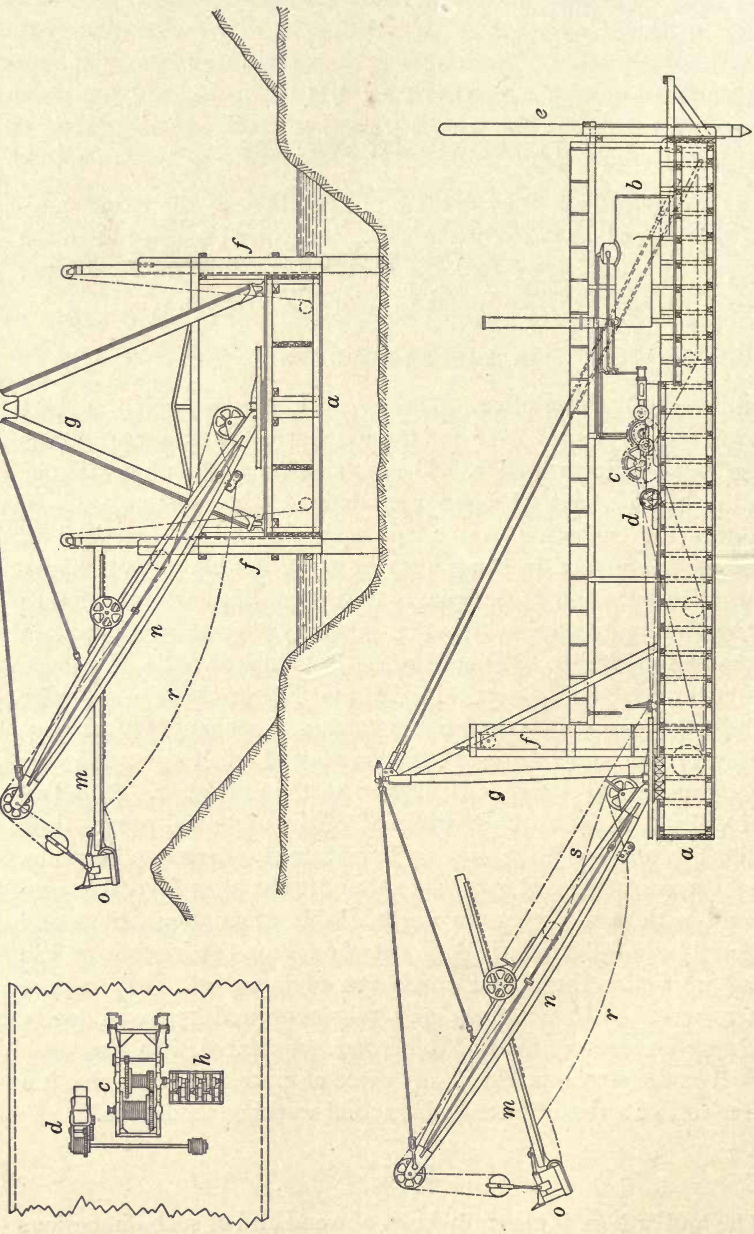


Diagram of Floating Dipper Dredge with Vertical Spuds.
Figure 74.

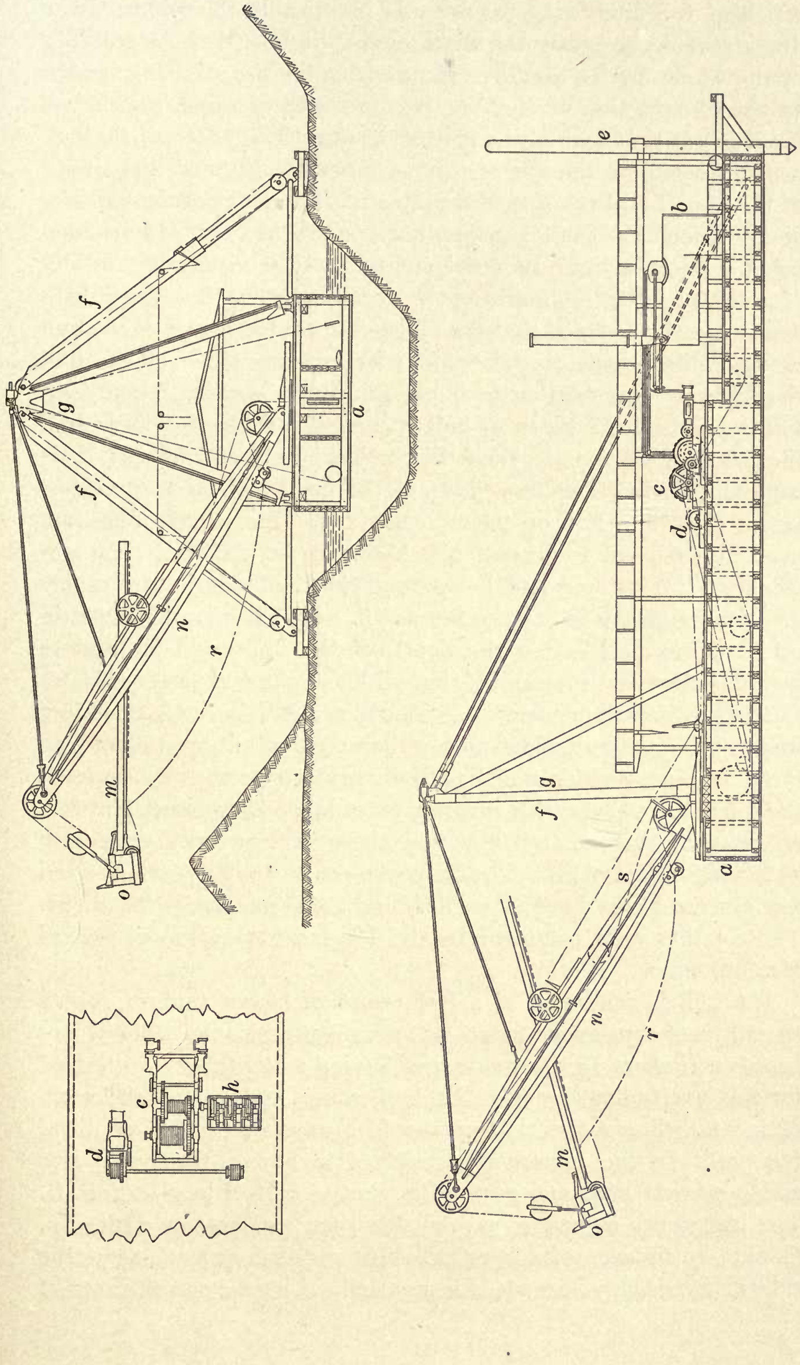


Diagram of Floating Dipper Dredge with Bank Spuds.
Figure 75.

width of the ditch may require. If practicable the width of the dredge should be nearly the width of the ditch so that the stability of the whole dredge may be enhanced by the use of bank spuds. In the construction of ditches, the top width of which exceeds 60 ft., it is not practicable to use bank spuds. The width of the hull depends solely on the size of the machinery to be used, the length of the boom, and the size of the dipper. The width of the hull of a dredge using bank spuds is generally made less than that of a machine using vertical spuds. It is evident that the tendency of the hull of a dredge to tip sideways, as the boom is swung to one side, will depend on the distance that the dipper is from the center of the hull or upon the length of the boom. Hence, the width of the hull should bear some relation to the length of the boom. When bank spuds are used the width of hull is generally made about one-half the length of the boom, while with vertical spuds the hull width is generally made about five-eighths of the length of the boom. See tables XIX and XX on pages 168 to 171. The length of the hull must be sufficient to provide suitable space for the boiler, the machinery, "A"-frame and boom, but principally it must provide sufficient stability to balance the weight of the boom and dipper in their various positions. The depth of the hull must be built to furnish sufficient displacement, but with as light draft as possible so as to float in shallow water. The early practice in dredge building was to make the hull wider on top than on the bottom, thus giving the sides a slope which would partially conform to the side slopes of the ditch. However, this involves extra labor in construction with no material benefit, and it is now the universal practice to build hulls with vertical sides. The dimensions of the hulls of various-sized dredges are given in Tables XIX and XX on pages 168 to 171. These tables were compiled by the Marion Steam Shovel Co., of Marion, Ohio.

The hull is composed of a framework of heavy timbers, which should be of continuous length as far as is practicable. The writer has seen timbers 14 in. square and having a length of 87 ft., used for the longitudinal bracing of a hull, which had an overall length of 110 ft. Transverse timbers should always be the full width of the hull. In the construction referred to above, transverse sills and caps were used and were 30 in. square with a length of 40 ft. The framework is covered on the sides, top and bottom with 3-in. plank. In the case of a large hull with very heavy machinery, the sides and ends may be made of heavy timbers, placed one on another.

All timbers should be well bolted together; although in small hulls of light construction, the planking is generally spiked to the framework. Yellow pine and fir are generally used and as both woods are about equal in strength, the preference is given to the cheaper. Great care should be taken in framing and splicing timbers, so as to secure strong joints, which should stagger where practicable.

To much care cannot be taken in the construction of the hull to secure the greatest strength and rigidity possible. When a dredge is in operation, extremely severe strains of every kind are being applied in rapid succession. The joints of the planking on the sides, ends and bottom must be made watertight. This is done by fitting the adjacent planks together so as to leave a V-shaped joint, with an opening of about $\frac{1}{8}$ in. on the outside surface. Three threads of clean oakum should be driven tightly into the joints, until the surface of the oakum is about $\frac{1}{2}$ in. below the outside surface. This space should then be filled with hot coal-tar. It is not necessary to calk the deck joints, unless the dredge is to be towed through rough water.

It is rarely practicable to move a dredge from one job to another and so it is generally dismantled for shipment by railroad. If the length of shipment is great, it is more economical to build a new hull, rather than to move the old one. Recently, the manufacturers of a steel dredge have constructed a steel hull, which is made in sections, which can be readily bolted together.

On deep-water dredges the boiler, coal bunkers and heavier machinery are placed on the bottom of the hull to secure maximum stability. On ditching dredges, however, it is the custom to place the boiler, coal bunkers, water tank, condenser, etc., on the rear end of the deck, which is from 1 to 2 ft. lower than the main deck. See Figs. 74 and 75.

BOILER

The use of a boiler on a floating-dipper dredge is very similar to that on a drag-line excavator and the reader is referred to the description on pages 107 to 109 of boilers for dry-land excavators.

It would be well to emphasize a few important points and recommendations, which have been previously mentioned.

The locomotive fire-box type has been generally found to be the most satisfactory to meet the exacting conditions of dredge work. It is easily adaptable to the consumption of various grades and kinds of fuel and can be easily cleaned. The Scotch-marine type of

TABLE XIX

DITCHING DREDGES WITH VERTICAL SPUDS

Dippers—$\frac{3}{4}$ to 4 yd.; Booms—30 to 100 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
4	100	36–40	28	85–100	$120\times50\times8\frac{1}{2}$	$2–12\times16$	$2–9\times9$	1500–3000	195
4	90	32–36	26	75–90	$120\times46\times8\frac{1}{2}$	$2–12\times16$	$2–9\times9$	1500–3000	180
$2\frac{1}{2}$	80	30–34	24	67–80	$100\times42\times8$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	135
$2\frac{1}{2}$	75	28–32	23	63–75	$100\times40\times8$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	128
$2\frac{1}{2}$	70	26–30	22	60–70	$100\times38\times8$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	122
$2\frac{1}{2}$	65	24–28	21	55–65	$90\times36\times7\frac{1}{2}$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	98
$2\frac{1}{2}$	60	22–26	20	51–60	$90\times34\times7\frac{1}{2}$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	92
$2\frac{1}{2}$	55	20–24	18	47–55	$90\times32\times7\frac{1}{2}$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	87
$2\frac{1}{2}$	50	18–22	16	43–50	$90\times30\times7\frac{1}{2}$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	81
$2\frac{1}{2}$	45	16–20	14	39–45	$90\times28\times7\frac{1}{2}$	$2–10\frac{1}{2}\times12$	$2–8\times8$	1000–2000	76
2	65	24–28	21	55–65	$85\times36\times7$	$2–9\times11$	$2–7\times8$	800–1600	86
2	60	22–26	20	51–60	$85\times34\times7$	$2–9\times11$	$2–7\times8$	800–1600	81
2	55	20–24	18	47–55	$80\times32\times7$	$2–9\times11$	$2–7\times8$	800–1600	76
2	50	18–22	16	43–50	$80\times30\times7$	$2–9\times11$	$2–7\times8$	800–1600	68
2	45	16–20	14	39–45	$80\times28\times7$	$2–9\times11$	$2–7\times8$	800–1600	63
2	40	15–18	12	35–40	$80\times26\times7$	$2–9\times11$	$2–7\times8$	800–1600	59

TABLE XIX.—*Continued*

DITCHING DREDGES WITH VERTICAL SPUDS

Dippers—$\frac{3}{4}$ to 4 yd.; Booms—30 to 100 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
$1\frac{1}{2}$	55	20–24	18	47–55	$75\times32\times6\frac{1}{2}$	$2–8\times10$	$2–6\times7$	600–1200	63
$1\frac{1}{2}$	50	18–22	16	43–50	$75\times30\times6\frac{1}{2}$	$2–8\times10$	$2–6\times7$	600–1200	59
$1\frac{1}{2}$	45	16–20	14	39–45	$70\times28\times6\frac{1}{2}$	$2–8\times10$	$2–6\times7$	600–1200	51
$1\frac{1}{2}$	40	15–18	12	35–40	$70\times26\times6\frac{1}{2}$	$2–8\times10$	$2–6\times7$	600–1200	48
$1\frac{1}{2}$	35	14–16	10	30–35	$70\times24\times6\frac{1}{2}$	$2–8\times10$	$2–6\times7$	600–1200	44
$1\frac{1}{4}$	45	16–20	14	39–45	$65\times28\times6$	$2–8\times8$	$2–5\frac{1}{2}\times6$	500–1000	44
$1\frac{1}{4}$	40	15–18	12	35–40	$65\times26\times6$	$2–8\times8$	$2–5\frac{1}{2}\times6$	500–1000	41
$1\frac{1}{4}$	35	14–16	10	30–35	$65\times24\times6$	$2–8\times8$	$2–5\frac{1}{2}\times6$	500–1000	38
1	40	15–18	12	35–40	$60\times24\times5\frac{1}{2}$	$2–7\times8$	Friction	400–800	32
1	35	14–16	10	30–35	$60\times22\times5\frac{1}{2}$	$2–7\times8$	Friction	400–800	29
1	32	13–15	9	27–32	$60\times20\times5\frac{1}{2}$	$2–7\times8$	Friction	400–800	27
$\frac{3}{4}$	35	14–16	10	30–35	$55\times22\times5$	$2–6\frac{1}{2}\times8$	Friction	300–600	25
$\frac{3}{4}$	32	13–15	9	27–32	$55\times20\times5$	$2–6\frac{1}{2}\times8$	Friction	300–600	22
$\frac{3}{4}$	30	12–14	8	25–30	$55\times18\times5$	$2–6\frac{1}{2}\times8$	Friction	300–600	20

TABLE XX

DITCHING DREDGES WITH BANK SPUDS

Dippers—¾ to 2½ yd.; Booms—30 to 80 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
2½	80	30–34	24	67–80	100×36×8	2–10½×12	2–8×8	1000–2000	115
2½	75	28–32	23	63–75	100×34×8	2–10½×12	2–8×8	1000–2000	109
2½	70	26–30	22	60–70	100×32×8	2–10½×12	2–8×8	1000–2000	103
2½	65	24–28	21	55–65	90×30×7½	2–10½×12	2–8×8	1000–2000	81
2½	60	22–26	20	51–60	90×28×7½	2–10½×12	2–8×8	1000–2000	76
2½	55	20–24	18	47–55	90×26×7½	2–10½×12	2–8×9	1000–2000	70
2½	50	18–22	16	43–50	90×24×7½	2–10½×12	2–8×8	1000–2000	65
2½	45	16–20	14	39–45	90×22×7½	2–10½×12	2–8×8	1000–2000	60
2	65	21–28	21	55–65	85×30×7	2–9×11	2–7×8	800–1600	72
2	60	22–26	20	51–60	85×28×7	2–9×11	2–7×8	800–1600	67
2	55	20–24	18	47–55	85×26×7	2–9×11	2–7×8	800–1600	62
2	50	18–22	16	43–50	80×24×7	2–9×11	2–7×8	800–1600	54
2	45	16–20	14	39–45	80×22×7	2–9×11	2–7×8	800–1600	50
2	40	15–18	12	35–40	80×20×7	2–9×11	2–7×8	800–1600	45

TABLE XX.—*Continued*

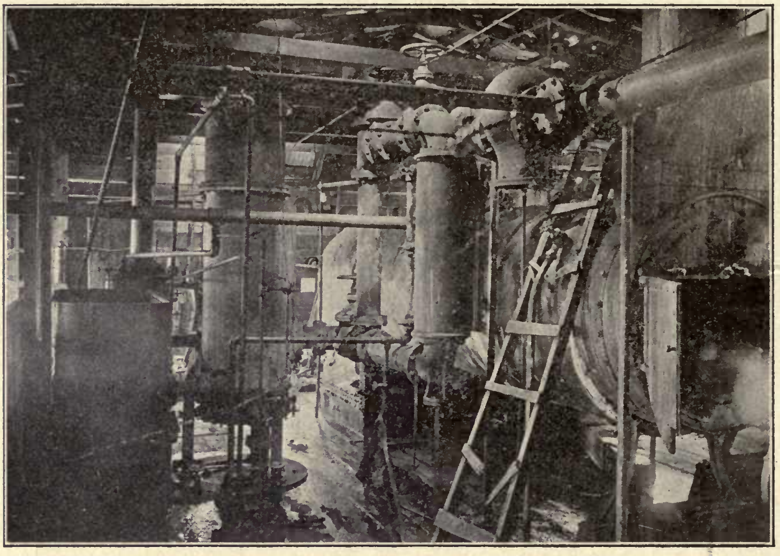
DITCHING DREDGES WITH BANK SPUDS

Dippers $\frac{3}{4}$ to $2\frac{1}{2}$ yd.; Booms—30 to 80 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
$1\frac{1}{2}$	55	20–24	18	47–55	$75\times25\times6\frac{1}{2}$	$2-8\times10$	$2-6\times7$	600–1200	49
$1\frac{1}{2}$	50	18–22	16	43–50	$75\times23\times6\frac{1}{2}$	$2-8\times10$	$2-6\times7$	600–1200	45
$1\frac{1}{2}$	45	16–20	14	39–45	$70\times21\times6\frac{1}{2}$	$2-8\times10$	$2-6\times7$	600–1200	39
$1\frac{1}{2}$	40	15–18	12	35–40	$70\times19\times6\frac{1}{2}$	$2-8\times10$	$2-6\times7$	600–1200	35
$1\frac{1}{2}$	35	14–16	10	30–35	$70\times17\times6\frac{1}{2}$	$2-8\times10$	$2-6\times7$	600–1200	31
$1\frac{1}{4}$	45	16–20	14	39–45	$65\times20\times6$	$2-8\times8$	$2-5\frac{1}{2}\times6$	500–1000	32
$1\frac{1}{4}$	40	15–18	12	35–40	$65\times18\times6$	$2-8\times8$	$2-5\frac{1}{2}\times6$	500–1000	28
$1\frac{1}{4}$	35	14–16	10	30–35	$65\times16\times6$	$2-8\times8$	$2-5\frac{1}{2}\times6$	500–1000	25
1	40	15–18	12	35–40	$60\times18\times5\frac{1}{2}$	$2-7\times8$	Friction	400–800	24
1	35	14–16	10	30–35	$60\times16\times5\frac{1}{2}$	$2-7\times8$	Friction	400–800	22
1	32	13–15	9	27–32	$60\times15\times5\frac{1}{2}$	$2-7\times8$	Friction	400–800	20
$\frac{3}{4}$	35	14–16	10	30–35	$55\times15\times5$	$2-6\frac{1}{2}\times8$	Friction	300–600	17
$\frac{3}{4}$	32	13–15	9	27–32	$55\times14\times5$	$2-6\frac{1}{2}\times8$	Friction	300–600	16
$\frac{3}{4}$	30	12–14	8	25–30	$55\times13\times5$	$2-6\frac{1}{2}\times8$	Friction	300–600	15

boiler is usually considered to be the more economical of fuel, the more durable and the safer of these two types, which are used on dredges. However, the writer has often seen the two types used on two dredges on the same job, and the locomotive type always gave the more efficient and economical service. See Fig. 76.

It is generally necessary to use a water purifying system on a dredge, because the available water supply is either surface water from swamp or marshes or from shallow wells. This water is usually highly impregnated with magnesia, lime, or the sodium salts.



Boiler and Piping System of Floating Dipper Dredge.
Figure 76.

These are all serious scale-forming materials and they should be removed from the water before it is fed into the boiler. A feed-water heater and purifier is the best means of accomplishing this result.

The writer has recently seen two boilers used on one dredge. These were placed side by side and connected so that the two could be used together or singly. The advantages of such a duplicate equipment are facility for cleaning without stopping the operation of the dredge and the use of extra power when needed for heavy or frozen-soil excavation. This novel installation means a greater

initial cost, but cases could be cited where it would have saved the extra expense several times over.

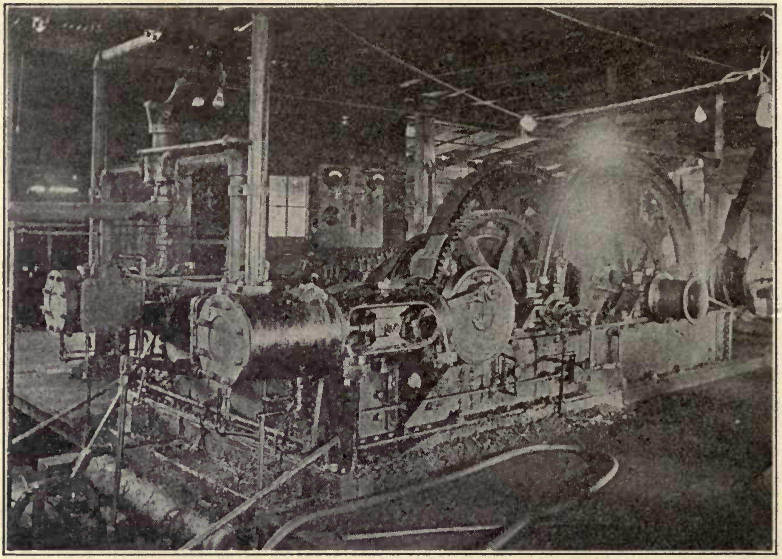
ENGINES

The main engine for a dipper dredge is very similar to that used on a drag-line excavator. It should be some standard type of horizontal, double-cylinder, friction-drum engine, which must be self-contained on a cast-iron or structural steel bed plate. There must be two drums, one for the hoisting cable and one for the backing cable. These drums are generally grooved to hold the first layer of cable in place, and are controlled by outside friction bands, which are operated by steam-actuated rams attached to the spokes of the large gear wheel. Provision should be made in these rams for the automatic compensation of contraction and expansion in the wheel. The backing drum should be provided with a reducing valve which automatically regulates the steam pressure to the load applied. This eliminates the jerking and snapping of the backing cable.

The size and power of engine required depends upon the size of the bucket and the length of the boom. The power of an engine is determined by the dimensions of its cylinders. These required by the various size dredges are shown in Tables XIX and XX, pages 168 to 171. As the engine on a dredge is run intermittently and at low speed it is preferable to have an engine cylinder of small diameter and long stroke. Too much emphasis cannot be put upon the necessity of having all the parts of the engine very strongly built. The continual application and removal of the load brings vibratory strains upon the machinery, which, unless built of the very best material and of ample strength, will be subject to frequent breaks. The latter mean shutting down dredging operations and the expenditure of time and expense in repairs. A frequent cause of trouble and delay in the operation of a dredge engine is the binding of the friction clutches. This is caused by the excessive heating of the friction surfaces, which are usually composed of hard-wood blocks or a vulcanized fiber. Experience has shown that little trouble is derived from this source if the diameter of the friction section is made from two and one-half to three times that of the main barrel of the drum. The main engine of a well-known make of floating-dipper dredge is shown in Fig. 77.

The swinging engines of dredges which have a dipper capacity greater than 1 cu. yd. are generally independent of the main engine. For the

$\frac{1}{2}$ cu. yd., the $\frac{3}{4}$ cu. yd., and 1 cu. yd. sizes of dredge the swinging mechanism consists of two independent swinging drums, which are attached to a long shaft, geared to the main engine. This method of operation is shown in Fig. 79. A chain or wire rope extends from one drum around the turntable or swinging circle to the other drum. After the dipper is raised out of the channel to the proper point, the hoisting drum is shut down and power applied to revolve the swinging drum shaft. One drum is set by the friction and winds up the chain

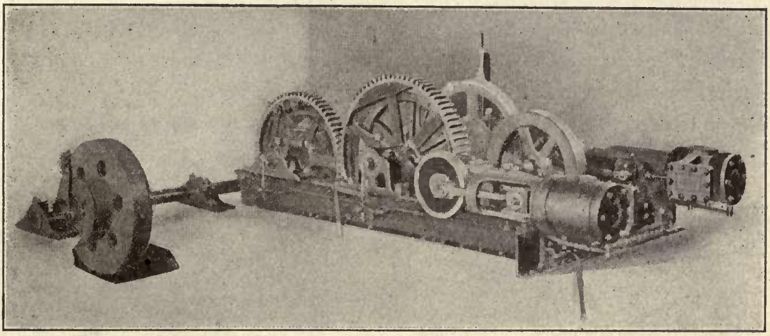


Hoisting Engine of Floating Dipper Dredge.
Figure 77.

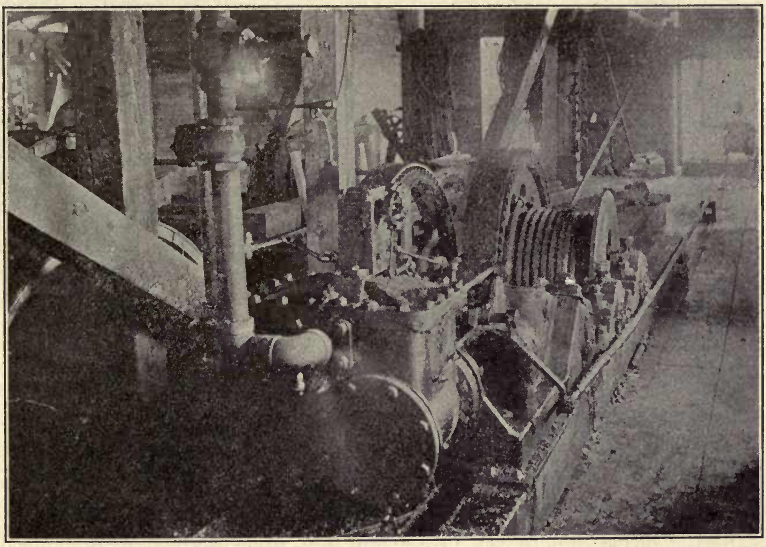
or cable, which in turn unwinds from the other or loose drum. The advantages of this method are the cheapness of construction and economy of space in using one engine. The disadvantages are the necessity of using the hoisting engine in order to operate the swinging device, the difficulty of keeping the swinging cable or chain taut and the waste of power.

In nearly all makes of dredges over 1 cu. yd. capacity a separate swinging engine is used. The type of engine used is one which is reversible and operated by a balanced throttle valve. The engine is compound geared to a long shaft, having two drums placed at such distance apart so as to give a direct pull to the swinging circle on

either side. A chain or steel cable extends from the bottom side of one drum to the swinging circle or turntable and thence to the top side of the other drum. Where it is desired to swing the boom, the



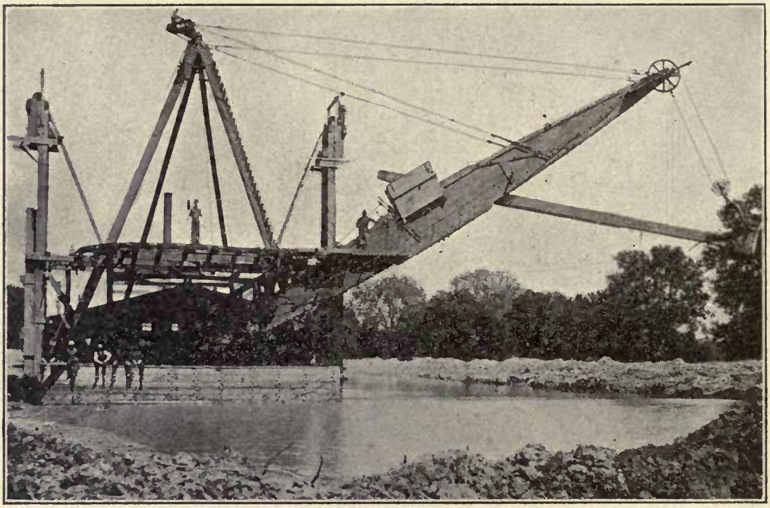
Combined Hoisting and Swinging Engine of Floating Dipper Dredge.
Figure 78.



Swinging Engine of Floating Dipper Dredge.
Figure 79.

swinging engine is operated and the cable or chain winds up on one drum as fast as it unwinds on the other. A typical swinging engine is shown in Fig. 79.

The swinging circle or turntable may be either fixed or movable and may be placed either just above or several feet above the deck. For dredges of dipper capacity up to 2 cu. yd. most manufacturers use a solid deck swinging circle. This consists of drum-shaped framework of steel plates and a side web of channels. In the center of the circle is a large cast ring, which rests and revolves upon the main base casting, which is fastened to the front edge of the deck. The lower end of the boom is pivoted on this cast ring and revolves with the swinging circle. Several loop rods are generally used to connect



Floating Dipper Dredge Excavating Drainage Ditch.
Figure 80.

the outer rim of the circle at the ends of its transverse diameter with the boom at points on either side and about one-fourth of its length. The diameter of the swinging circle should be sufficient to give a direct pull from the drums of the swinging engine and also not less than one-fifth of the horizontal reach of the boom. Since the rim of the swinging circle, where the pull from the cable is applied, is several feet lower than the points on the boom where the pull is transferred from the rim of the circle to the boom by the rods or braces, there results a tilting action. This causes a loss of power and a warping of the swinging circle. To overcome this eccentricity in the transference of the pull, the swinging circle is often placed on the upper end of a mast, which rests on the lower pivot casting and revolves the circle

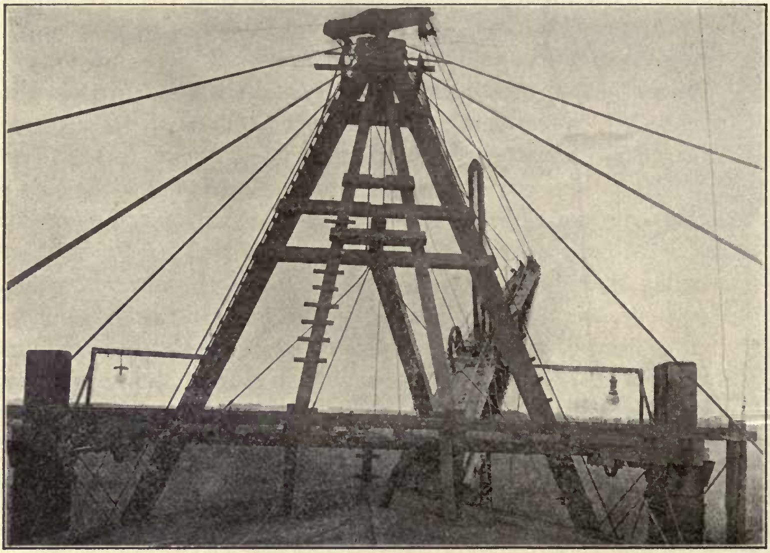
in a plane 8 or 10 ft. above the deck. The circle, in this case, is braced to the boom in the plane of the rim and thus a direct pull is obtained. This method is advantageous when the boom is longer than 60 ft. The objections to this method are first, it places considerable weight above the deck and decreases the stability of the dredge; second, it requires a special arrangement of sheaves to lead the swinging cable from the drums to the circle and a resulting loss of power and increased wear on the cable.

Where the dipper is of large capacity and the boom of great length (over 70 ft.), a stationary turntable is generally used. The turntable is placed just above the deck or several feet above, as has been explained for the swinging circle. The stationary circle consists of a circular rim and several spokes, which are of structural steel and fastened to the central cast pivot and the deck of the hull. The swinging chain or cable leads from drums to the turntable where it passes over small sheaves placed in the rim. In this case, since the circle is fixed in position, its diameter is not dependent on the reach of the boom, but should be large enough so that the power may be applied at a distance from the foot of the boom to give a direct and uniform pull. The boom is connected to the axis of rotation by a large timber fastened to a swinging chain or cable at the point where they cross. Then the movement of the chain or cable drives the boom, which is pivoted to its lower end.

A-FRAME

The A-frame is a tower or frame composed of large timbers securely seated on the top of the hull at each side near the front and joined together at the top with a cast-steel head and yoke. This frame is generally composed of two main legs in a nearly vertical plane, inclined toward the front at a slope of about 1 in 6, and stayed by guy rods extending from the head block of the frame to the sides of the hull near the rear end. Some dredge builders use two rear legs or timbers as braces and in this case the two main legs are set in a vertical plane. It is necessary that the A-frame be strongly braced and held rigidly in position as the pull from the outer and loaded end of the boom is largely borne by the top of the A-frame. A break or failure of any part of this frame would probably result in serious loss of life and damage to the dredge. The height of the A-frame is largely governed by the maximum required elevation of the end of the boom which will be determined by the depth of excavation and

distance away from the ditch to the place where the excavated material must be deposited. The top of the head block is a large pin on which the yoke revolves. The yoke is a short-trussed beam to the ends of which are attached the cables which support the outer end of the beam. See Fig. 81 for typical A-frame details.

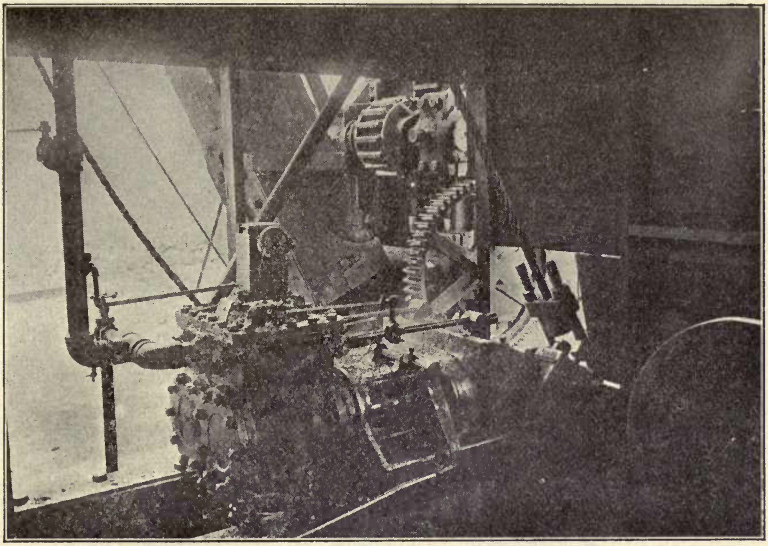


A-frame of Floating Dipper Dredge.
Figure 81.

SPUDS

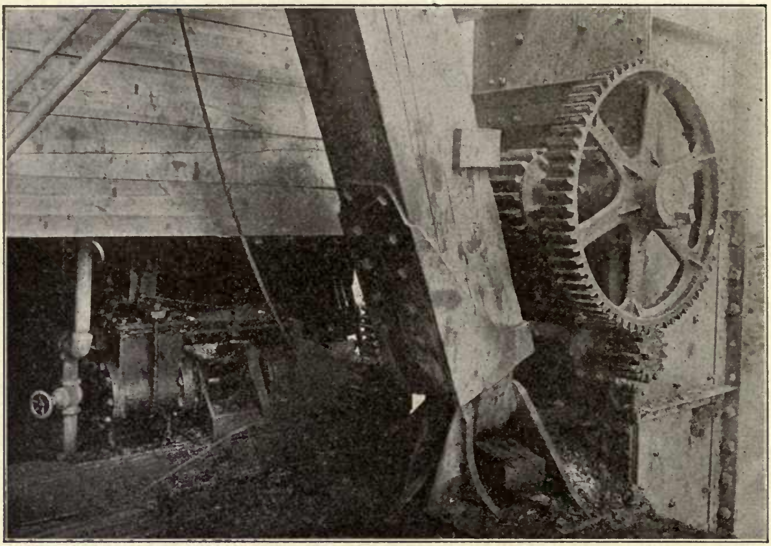
To hold the hull horizontal and to prevent its being tipped about while the dredge is in operation, three leg braces or spuds are provided. One is placed in the middle of the rear end of the hull and one on each side near the front. When the ditch is narrow and the dredge has a hull nearly the width of the ditch, bank spuds are used. As shown in Fig. 87, these inclined bank spuds are pivoted to the head block of the A-frame and the lower ends are pivoted to large platforms which transmit the pressure to the soil. Some manufacturers use a rectangular spud frame, which is placed just behind the A-frame. At the upper corners of the spud frame are bolted plates supporting pinions or dogs, which engage the teeth of racks fastened to the lower sides of the spuds. This simple mechanism serves to lock the spuds in place. Short braces connect the lower ends of the spuds with the sides of the

hull at the feet of the A-frame. Vertical side spuds are used in a wide ditch and their lower ends bear directly on the bottom of she ditch. The rear spud is always vertical and is used to prevent the dredge from swinging about during its operation. Each spud is a large solid timber which moves inside of an iron or timber box or guide frame. This is the new form of telescopic spud. Teeth on a rack fastened to the lower side of the spud engage a pinion on the lower side at the end of the box section.

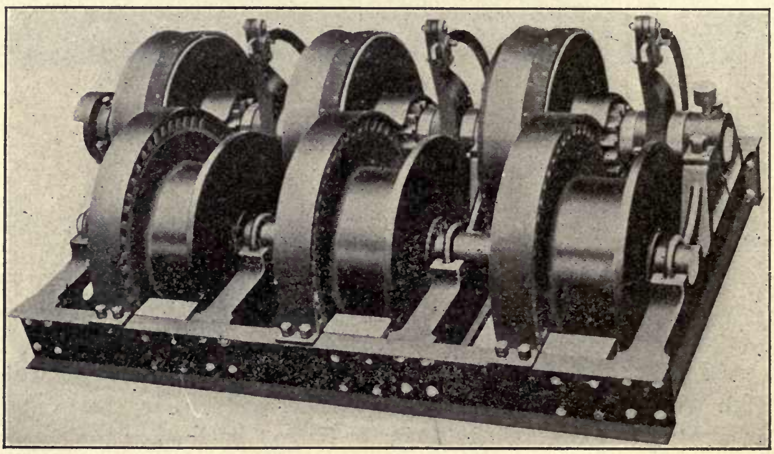


Spud Engine of Floating Dipper Dredge.
Figure 82.

The spuds are raised and lowered by means of steel-wire ropes passing over sheaves and controlled by special drums. These drums are mounted on a separate bed plate and their shaft is connected to the end of the backing drum shaft by a jaw clutch, which is disengaged when the spuds are not to be operated. Fig. 84 shows a typical spud hoist. In large dredges, where vertical spuds are used, they are often operated by a steam cylinder fastened to the front of each spud and controlling a brake or clamp, which encircles the spud and is attached to the piston of the cylinder. This method is cumbersome, troublesome to operate, and uneconomical of power. This has been replaced by the installation of a separate engine to operate each



Spud Hoisting Mechanism of Floating Dipper Dredge.
Figure 83.



Spud Hoist of Floating Dipper Dredge.
Figure 84.

of the front spuds. This allows each spud to be operated independently and without using the main engine. The details of such a spud engine are shown in Figs. 82 and 83.

Wherever it is possible it is best to use the inclined bank spuds of the telescopic type. These braces take the load from the top of the A-frame to the banks along the sides of the ditch and thus remove much strain from the hull of the dredge. As the stability of the dredge when in operation depends to a great extent upon the strength and proper working of the spuds, it is necessary that they be made amply large and provided with a strong and reliable locking device. The spuds must be raised and lowered each time the dredge makes a move, hence, it is evident that the ease and rapidity of their operation will greatly affect the progress of the work.

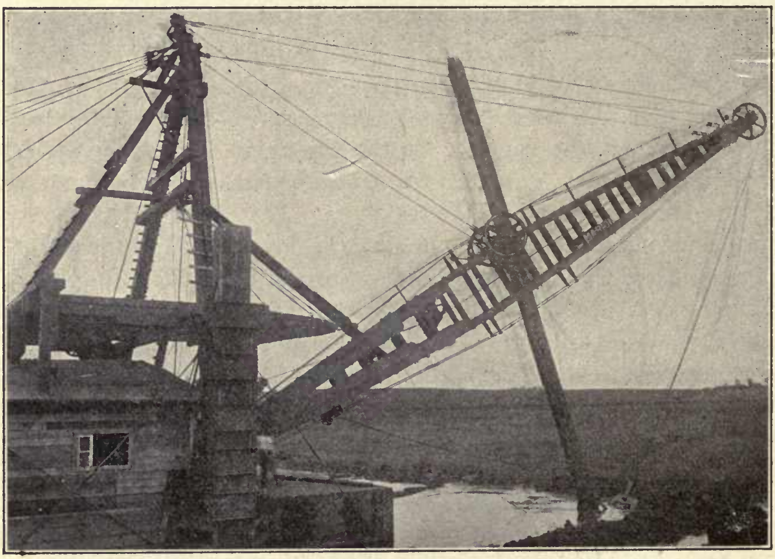
BOOM

The boom or crane is a fish-bellied shaped beam, usually constructed of wood. It is made in two equal parts or sections and so spaced apart that the dipper handle may work between them. When the length of the boom is over 70 ft., it is often made of trussed timbers to secure lightness with strength. See Fig. 85. For lengths up to 70 ft., however, the webs of the booms are generally made solid. See Fig. 80. When the capacity of the dipper is over $2\frac{1}{2}$ cu. yd., dredge builders often use a steel-trussed beam, similar in construction to those used on the drag-line excavators. The length of the boom depends on the capacity of the dredge, the cross-section of the ditch to be excavated, and distance from the center of the ditch to the place where the excavated material must be deposited. The width of the boom at the ends need only be enough to provide sufficient bearing for the end castings. The width at the center should be from one-tenth to one-twelfth of the length of the boom. As has been stated under "*Hull*," the length of boom should bear a definite relation to the width of the hull. When vertical spuds are used the length of boom should be about one and one-half times the width of the hull, while with the use of bank spuds, the length may be increased to twice the width of the hull. The lower end of the boom is pivoted to the swinging circle or upper section of the cast pivot. The outer end is connected to the yoke at the top of the A-frame by means of adjustable wire cables. At the outer end of the boom is the sheave over which the hoisting cable passes on its way from the sheave attached to the bail of the dipper to the fair lead sheaves at the lower end of the boom and thence to the drum of the main engine. On top

of the boom and a little below the center is placed the brake shaft, upon which the dipper handle moves. This mechanism consists of two large wheels whose motion is controlled by friction brakes. These wheels connect a pinion over whose periphery moves a toothed rack fastened to the lower side of the dipper handle. When the friction bands are released the weight of the dipper and its handle allows the latter to move downward as fast as the hoisting cable is paid out. When the dipper is filled and has been raised to a suitable position for swinging the boom, the application of the friction brakes holds the dipper handle in place while the boom is being swung to one side. For ease of operation the diameter of the brake wheels should be about one-twentieth of the length of the boom.

DIPPER

The dipper handle works in conjunction with the boom and carries the excavator or dipper at its lower end. Usually it is a large square



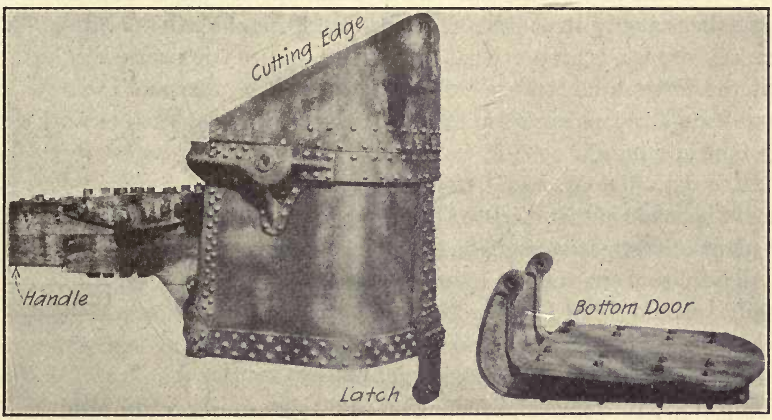
Boom and Dipper Handle of Floating Dipper Dredge.
Figure 85.

timber whose corners are reinforced with angle irons. See Figs. 80, 85 and 87. The lower side is provided with a cog rack, which moves over the pinions, mounted on the top of the boom. The cross-section

of the handle depends on the size of the dipper and the resulting maximum load to be carried. Its length should be about two-thirds that of the boom. It should be made amply large to resist the bending caused by the prying action of the dipper in loosening hard or tough material.

DIPPER HANDLE

The dipper or bucket is of the same type as that used on steam shovels. A reference to Fig. 86 will clearly show the details of construction. The sides are made of heavy steel plates which are strongly reinforced by steel bars at the top and bottom. For ordinary material the cutting edge is made of a single bent plate, which can be easily replaced when worn out. When compact and hard soils are to be excavated, large steel teeth are used to reinforce the cutting edge. The bottom is a heavy steel plate, which is hinged to the back of the dipper



Dipper of Floating Dipper Dredge.
Figure 86.

and is held in place by a spring latch riveted to the front of the dipper. The latch is opened by the pulling of a cable or chain, which extends back along the boom to the craneman. As soon as the dipper is lowered the weight of the door causes it to automatically close and latch. The size or capacity of the dipper varies from $\frac{1}{2}$ to 5 cu. yd., and this element is governed by the size of the dredge. This is dependent on the size of the ditch to be excavated, the amount and character of the material, and the amount of money available for the

construction of the dredge. Generally, the dredge contractor builds his hull, when practicable nearly as wide as the ditch so as to use bank spuds, or in the case of wide ditches or canals (over 50 ft. wide on top), he makes the boat wide enough to excavate the canal in two cuttings. He then uses the largest size dipper which can be used with the size and strength of hull. The larger the dipper used, the larger the machinery and boiler required to operate the dredge, but it should be noted that six men can operate a $3\frac{1}{2}$-cu. yd. dredge as well as a $1\frac{3}{4}$-cu. yd. machine. The principal difference in the cost of operation would be in the amount of fuel used.

GENERAL DETAILS

The general principles of design and construction which apply to any piece of machinery are especially noteworthy in the case of a floating dipper dredge. Care must be taken to have all parts rightly proportioned and coördinated. Always use the simplest details and make them amply strong. The output, and therefore the profitableness of a dredge, is proportional to the time that the dipper is working and the forge is not in use. Breakdowns and repairs are not only troublesome and expensive in themselves, but they mean loss of working time and income.

All gears, pinions, racks, important castings and cutting edges should be made of cast steel. All straps, bands, rods, and bolts should be made of first grade wrought iron, such as Norway iron.

All solid timbers, such as are used for the spuds, A-frame, and dipper handle, should be of heart wood, straight grained, free from shakes, twists, decay, large pitch pockets, or other defects. Long-leaf yellow pine, Douglas fir, or white oak should be used.

Wire rope or cable made of plow steel wire is generally used in preference to chain. The wire rope is cheaper, lighter, takes up less room on the drums and sheaves and gives warning of failure by the preliminary breaking of a few strands. The chain, however, will break a link and pull apart suddenly and often cause a bad accident. Some dredge builders still use a chain for operating the swinging circle or turntable. The friction of a wire rope is less and more uniform than that of a chain.

The sheaves should be of as large diameter as possible, usually not less than 30 times the diameter of wire cable used on it. They should be made of an excellent grade of gray cast iron and be provided with phosphor-bronze bushings. The pins must be of the highest grade of

medium steel and turned to fit accurately bored holes in the sheaves. The groove in the rim of the sheave should have a depth not less than three times the diameter of the wire rope. Where the cable is subject to jumping off the sheave, a suitable guard or housing should be provided.

As a chain is "as strong as its weakest link," so a dredge is as strong as its weakest part. Too much care cannot be taken in the building of a dredge to make every part amply strong, stronger than is estimated or required. It is an unwise and short-sighted policy to spare initial expense in the construction of any form of excavator. When economy is thus early practised, vexations and costly breaks and delays are almost sure to follow. The writer has seen cases of this kind when a fundamental weakness in a dredge caused break after break, until the men working on the machine actually came to believe that it was "hoodood" and refused to continue their work.

In order to avoid long delays due to breaks and repairs, duplicate parts of all the important sections of the machinery should be kept always on the dredge. Such parts would include cables, sheaves, bolts, pins, shafts, etc.

76a. Use in Colorado.—A standard make of floating dipper dredge was used during the year 1911 in the cleaning out and enlarging of a large supply canal on an irrigation project in eastern Colorado.

The material excavated was a sandy loam and an average of 373.5 cu. yd. were excavated in each 100-ft. length of canal. A total excavation of 394,387 cu. yd. was made in a total canal length of 20 miles and during 187 actual operating days. The dredge crews were on duty 268 days. The dredge was operated in two shifts of 10 hours each, and one hour per day was spent in oiling and cleaning the machinery.

Screened pea coal from New Mexico was used as fuel and water for the boiler was pumped directly from the canal. The deposition of mud and the formation of scale resulting from the use of this water caused considerable boiler trouble. A feed water heater was not used, although the purification of the water before feeding it to the boiler would doutless have saved time and expense.

The dredge had a wooden hull, 75 ft. long and 24 ft. wide. The boom had a length of 50 ft. and the dipper a capacity of $1\frac{1}{2}$ cu. yd. Marion anchors or bank spuds were used.

The cost of operation for the year is as follows:

Labor:

Scale of Wages

1 head engineer or runner,	@	$120.00 per month.	
1 runner,	@	110.00 per month.	
2 cranesmen,	@	55.00 per month.	
2 firemen,	@	45.00 per month.	
2 deck hands,	@	40.00 per month.	
1 teamster,	@	40.00 per month.	
1 cook,	@	50.00 per month.	
Total cost of labor for operating dredge,			$6,243.70
Cost of labor per cubic yard excavated,			0.0157

Fuel:

1,276.65 tons of coal @ $3.175 per ton,	$4,053.36
Cost of fuel per cubic yard excavated,	0.0103

Repairs and Maintenance of Machinery:

Total cost of cables, repairs and renewals of machinery,	$3,894.67
Cost of repairs and renewals per cubic yard excavated,	0.0098

Miscellaneous:

Total cost of miscellaneous supplies, oil, waste, grease, etc.,	$692.81
Cost of miscellaneous supplies per cubic yard excavated,	0.0012

Expense of Floating Dredge:[1]

Cost of retaining water in canal to keep the dredge afloat,	$369.24
Cost of floating dredge per cubic yard,	0.0009
Total cost of operating dredge for 187 days,	$15,253.78
Cost of operation per day,	81.57
Cost of operation per cubic yard excavated,	0.0372
Cost of dredge and house boat,	16,500.00

The following general and overhead expenses were included in this work.

[1] In cleaning out a canal it is often necessary to maintain a dam of excavated material in front of the dredge to provide a sufficient depth of water to float the dredge. In crossing another and existing stream, channel or waterway, a dam or dyke must be constructed on the down-stream side to prevent the loss of water through the original channel.

Engineering, supervision and office work,	$1,859.10
Team work in building up spoil bank and constructing road on the top for 20 miles, @ $236.08,	4,721.75
Removing and replacing 10 highway and 1 railroad bridges,	837.78
Right of way and legal expenses,	190.42
Interest on investment (8 per cent. of $16,500),	1320.00
Depreciation (20 per cent. of $16,500),	3,300.00
Total amount of general expenses,	$12,229.05
Amount of general expenses per cubic yard excavated,	0.0310
Total cost of work per cubic yard excavated,	0.0682

76b. Use in Florida.—Two floating-dipper dredges have been used recently in the construction of the large outlet canal located near Sebastian, Florida. The work of the four drag-line excavators in the excavation of this same canal was given on pages 124 to 125 inclusive. The dredges are being used (1911–13) to excavate the sections of the main canal with dense clay sub-soil, and the larger lateral ditches.

The larger dredge has an all steel hull 100 ft. long and 33 ft. wide, a 70 ft. boom and a 2½ cu. yd. dipper. The smaller dredge has a wooden hull 70 ft. long and 18 ft. wide, bank spuds, a 50-ft. boom and a 1½ cu. yd. dipper.

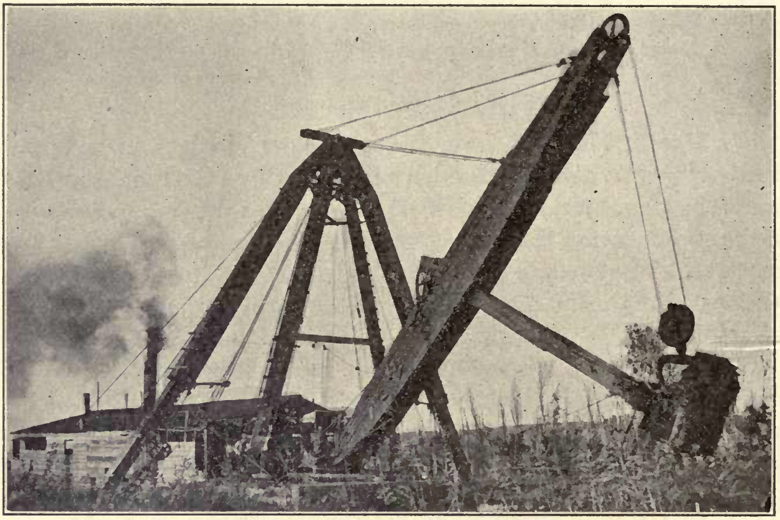
The average monthly excavation for the two dredges has been about 100,000 cu. yd. The cost of excavation (not including overhead charges and depreciation) has averaged 4¾ cents per cu. yd. Partially seasoned pine has been used for fuel and an average of two cords per shift of 10 hours, or 103 cords per month of 26 days, have been consumed.

76c. Use in South Dakota.—In the construction of the Clay Creek Ditch in Clay and Yankton Counties, South Dakota, during the years 1908, 1909, and 1910, one of the two floating-dipper dredges used made such uniform progress that an accurate cost record was kept of its operation.

This dredge had a wooden hull, 87 ft long., 30 ft. wide, and 6 ft. deep. The framework of the hull was composed of 54 keelsons, 8 in.×10 in.×30 ft. long and spaced about 3 ft. 3 in. on centers. The side and end verticals or posts were 6-in.×6-in. Douglas fir timbers, 6 ft. long and spaced 6 ft. in the clear. The sides, ends and bottom were formed of 3-in. yellow pine planking. The deck was made of 2-in. yellow pine planking. All main timbers were

strongly bolted together and the planking was spiked to the framework. The joints of the sides, ends and bottom were well calked with three strings of oakum, and then hot tar was applied until the joints were filled flush with the outer surface.

Marion anchors or bank spuds, attached to the head block of the A-frame were used. These anchors were made of 14-in.×14-in. oak timbers sliding in steel boxings, whose lower ends supported heavy



Dipper Dredge with Bank Spuds Excavating Drainage Ditch.
Figure 87.

platforms about 6 ft. square. The A-frame had a height of 44 ft., and was built of two 14-in.×16-in. timbers of Douglas fir. The rear spud was single-oak timber 10 in. square. The boom had a length of 66 ft., was 5 ft. deep in the center, had 8-in.×8-in. fir flanges and a web of 5-in. yellow pine. It was made in two equal sections. The dipper handle was made of two oak timbers, 10-in.×14-in. and having a length of 38 ft. Steam was furnished by a 60-h.p. boiler of the locomotive type. The main engine was built by the Marion Steam Shovel Co., and was equipped with two 9-in.×11-in. cylinders. The hoisting drum had a diameter of 30 in. and the backing drum 18 in. The diameter of the frictions was twice that of the drums. A separate swinging engine was used, and was equipped with two drums having a diameter of 18 in. A 3-in. chain connected the

drums with a steel swinging circle having a diameter of 17 ft. 4 in. A small dynamo was belt connected to the swinging engine and furnished light for the night operation of the dredge. Water was at first pumped directly into the boiler from the ditch, but as the water contained so much scale-forming impurities, it was found necessary to install a feed water heater and purifier, to purify the water before it was used in the boiler. Fig. 87 is a view of this dredge at work, equipped with a $1\frac{3}{4}$ yd. dipper.

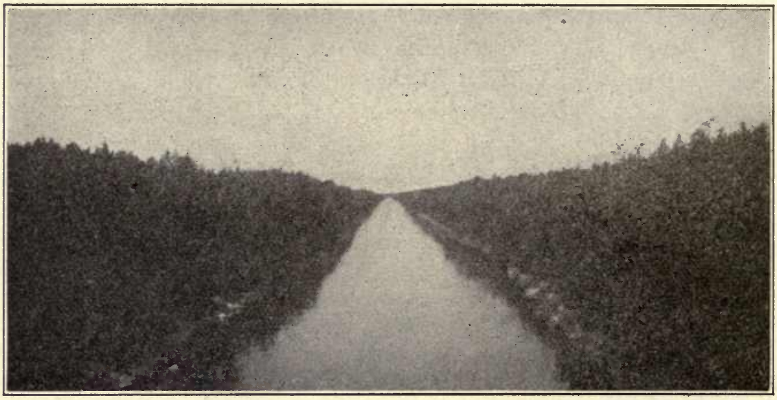
The following table gives the amount of excavation made by this dredge during the months when operation was uniform and uninterrupted by climatic conditions, floods, etc.

Month	Progress	Estimated excavation	Actual excavation	Surplus excavation
August, 1908......	5,750 ft.	54,227 cu. yd.	58,708 cu. yd.	4,481 cu. yd.
September, 1908...	4,600 ft.	54,395 cu. yd.	60,443 cu. yd.	6,048 cu. yd.
October, 1908.....	6,350 ft.	65,383 cu. yd.	74,753 cu. yd.	9,370 cu. yd.
November, 1908...	6,250 ft.	62,108 cu. yd.	67,279 cu. yd.	5,171 cu. yd.
December, 1908...	5,750 ft.	60,805 cu. yd.	63,894 cu. yd.	3,089 cu. yd.
April, 1909........	6,700 ft.	74,287 cu. yd.	79,310 cu. yd.	5,023 cu. yd.
May, 1909........	4,800 ft.	69,536 cu. yd.	75,401 cu. yd.	5,865 cu. yd.

The "surplus excavation" shows that the dredge excavated outside of the side slopes of 1 to 1 and the bottom grade, which were required by the specification and established by the side slope and grade stakes. This "surplus excavation" is necessitated by the fact that the dredge cannot excavate a true 1 to 1 side slope or uniformly to grade. The contractor is not paid for this extra work, but only for the excavation within the boundaries established by the stakes and the specification. During the seven months, as recorded in the table above, the average actual monthly excavation was 68,541 cu. yd., the average estimated monthly excavation was 62,963 cu. yd., making an average monthly surplus of 5,578 cu. yd. or about 9 per cent. During August, 1908, the dredge was working in the upper section of the ditch, whose cross-section was a base of 20 ft., average dpeth of $9\frac{1}{2}$ ft. and side slopes of 1 to 1. From September, 1908, to December, 1908, inclusive, the dredge was excavating a ditch the cross-section of which was a base of 25 ft., an average depth of 10 ft. and side slopes of 1 to 1. During April and May, 1909, the dredge worked in the ditch where the botton width was

30 ft., average depth of $10\frac{1}{4}$ ft. and side slopes of 1 to 1. The material excavated was loam to a depth of from 3 to 6 ft. and the remainder yellow clay. Fig. 88 shows a view of the ditch just after its excavation by the dredge illustrated in Fig. 87.

The work was carried on in two shifts of 10 hours each for six days a week. Sunday was spent in making small repairs, cleaning and boiling the machinery, rolling and replacing boiler tubes, etc.



Drainage Ditch excavated by Floating Dipper Dredge.
Figure 88.

The following schedule gives the cost of labor employed in the operation of the dredge:

2 engineers or runners,	@ $100 per month,	$200.00
2 cranesmen,	@ 75 per month,	150.00
2 firemen,	@ 60 per month,	120.00
4 laborers,	@ 50 per month,	200.00
1 cook,	@ 35 per month,	35.00
Total monthly labor cost,		$705.00
Total cost of labor for operating dredge,		$5,641.29
Cost of labor per cubic yard excavated,		0.0123

Fuel:

730 tons of coal @ $6.50 per ton,	$4,748.52
Cost of fuel per cubic yard excavated,	0.0103

Repairs and Maintenance:

Total cost of cables, bolts, pins, blocks, sheaves, oil, waste, grease, etc.,	$2,535.44
Cost of repairs and maintenance per cubic yard excavated,	0.0055

Board and Lodging:

Total cost of board and lodgings for 10 men and 1 woman cook for 200 days,	$1,417.03
Cost of board and lodging per cubic yard excavated,	0.0038
Total cost of operating dredge for 200 days,	$14,342.28
Cost of operation per day,	71.71
Cost of operation per cubic yard excavated,	0.0312
Initial cost of dredge (moving, erection and dismantling) and of house boat,[1]	$8,830.16

The following allowance is made for general and overhead expenses.

Supervision and general office expenses,	$2,000.00
Interest on investment (8 per cent. of $8,830.16),	706.41
Depreciation (20 per cent. of $8,830.16),	1,776.03
Total amount of general expenses,	$4,482.44
Amount of general expenses per cubic yard excavated,	0.0097
Total cost of work per cubic yard excavated,	0.0409
Contract price for excavation,	0.0800

76d. Use in Illinois.—An unusually good example of floating-dipper dredge work has recently been completed in Whiteside and Henry Counties, Illinois. The ditch was excavated through clay for the first 6 to 7 ft. in depth and underlaid by coarse sand. The latter gave very little trouble by filling in on account of the shallow depth of 2 to 3 ft. of that material. The ditch had a bottom width of 18 ft., an average depth of 8 ft. and side slopes of 1 to 1.

The length of the ditch was about $8\frac{1}{4}$ miles.

The dredge used was a Marion floating-dipper dredge, equipped with a 45-ft. boom and a $1\frac{1}{4}$ cu. yd. dipper. The average excavation was 41,070 cu. yd. per month, which would make the progress of the dredge about 1 mile per month. The total excavation was 334,000 cu. yd. and the actual operating time was 200 days of two 11-hour shifts each.

The following schedule gives the cost of labor employed in the operation of the dredge.

[1] The cost of boiler and engines was $6,000.

2 engineers or runners,	@ $3.13 per day,	$6.16
2 cranemen,	@ 1.85 per day,	3.70
2 firemen,	@ 1.45 per day,	2.90
2 deckmen,	@ 1.35 per day,	2.70
1 coalman,	@ 0.94 per day,	0.94

Total cost of labor per day (two 11-hour shifts),	$16.40
Total cost of labor for operating dredge,	$3,217.50
Cost of labor per cubic yard excavated,	0.0096

Fuel:

628 tons of coal @ $5 per ton,	$3,140.00
Cost of fuel per cubic yard excavated,	0.0094

Repairs and Maintenance:

Total cost of cables, bolts, pins, blocks, etc.,	$250.00
Cost of repairs and maintenance per cubic yard excavated,	0.0007

Board and Lodging:

Total cost of board and lodging for nine men and one cook for about eight months,	$795.60
Cost of board and lodging per cubic yard excavated,	0.0024
Total cost of operation of dredge,[1]	$7,403.10
Cost of operation per cubic yard excavated,	0.0221
Cost of operation per working day,	37.016
Initial cost of dredge (moving and erection),	5,000.00

It will be noted that the above costs are uniformly low for floating-dipper dredge operations. Conditions for continuous and successful work in this case were unusually favorable, such as pleasant weather, soft soil and few breakdowns. Due credit should here be given to careful and skilful operation of the machinery.

76e. Use in California.—The report of the progress of construction work on the Los Angeles aqueduct for the month of February, 1911, gives the following statement of dredging in Owens Valley.

The dredge consisted of a scow on which was mounted a Model 60, Marion electric shovel, equipped with a $1\frac{1}{2}$ cu. yd. dipper. The yardage is based on the theoretical section of the canal or 14.81 cu. yd. per lineal foot.

Following is the tabulated data:

[1] Not including interest on investment and overhead expenses.

TABLE XXI.
DREDGING OPERATION AND COSTS.

Item	Teams and men	Operation	Renewals and repairs	Miscellaneous	Totals
Men—number days	10	205	241	3	459
Live stock—number days	....	56	12	....	....
Lineal feet	....	2,625	....	....	....
Cubic yards	....	38,876	....	....	....
Labor costs	$34.29	$727.39	$838.81	$17.85	$1,618.34
Live stock costs	....	50.40	10.80	....	61.20
Cost of materials and supplies	....	1.75	120.32	....	122.07
Power cost	....	408.51	9.79	....	418.30
Freight cost	....	0.35	24.06	....	24.41
Total costs	34.29	1,188.40	1,003.78	17.85	2,244.32
Unit cost per cubic yard	0.0001	0.0306	0.0258	....	0.0565

76f. Use in Louisiana.—The reclamation of about 3,000 acres of swamp land in a district near New Orleans, La., comprised the excavation of two main canals having a bottom width of 18 ft. and an average depth of 7½ ft. The material excavated was what is known as "sharkey clay," which is silt deposited by the Mississippi River. The soil was wet, as the general elevation of the ground surface was about 5 ft. above sea level.

The excavators used were two Marion floating-dipper dredges, one with a ¾ cu. yd. dipper and the other with a 1½ cu. yd. dipper. The small dredge cost $8,500 to construct ready for operation. The whole plant was estimated as worth $20,500 at the commencement of the work. Crude oil was used for fuel and was hauled from New Orleans on two oil barges of 400 gal. capacity each, by a 25-h.p. gasoline tug.

The rate of wages paid were as follows:

Engineer,	$125.00 per month.
Craneman,	65.00 per month.
Fireman,	50.00 per month.
Laborers,	2.00 per day.

These rates include board and lodging.

Following is an estimate of the cost of operation from the latter part of 1909 to August, 1911.

Total excavation. 674,921 cu. yd.

Cost Per Cubic Yard:

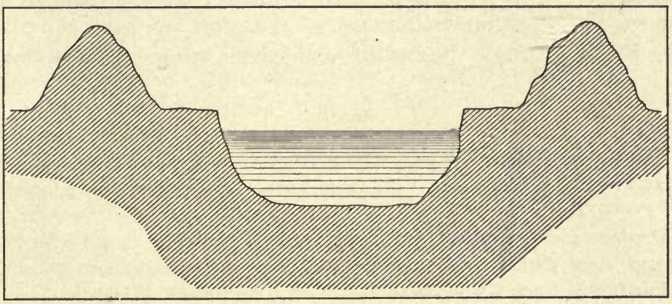
Plant (arbitrary),[1]	$0.0076
General,	0.0059
Repairs,	0.0020
Supplies,	0.0138
Fuel,	0.0094
Labor,	0.0219
Camp.	0 0081
Total cost per cubic yard,	$0.0687

77. Résumé.—The floating dredge, in its many forms, is the best-known and most popular class of machinery used in the construction of drainage canals and ditches. in England and on the Continent, the ladder and hydraulic dredges were early developed and have been generally used. In this country, the average dredge contractor has not been willing to put a large sum of money into a

[1]Based on a depreciation of 25 per cent. for two years' use. The above does not include interest or overhead expenses.

permanent plant, but has demanded returns on a smaller investment. For example, the English or French contractor will spend $100,000 for a ladder dredge with a daily capacity of 3,000 cu. yd., while the American contractor will be content to invest $40,000 in a less substantial dipper dredge of the same capacity, time being the chief element which the American considers.

A large part of open ditch work is done in low, swampy land where it is difficult for anything but a boat to move about. Thus it early becomes necessary to mount excavating machinery on a boat or hull in order to reach the scene of operations. The simplest form of excavator is a steam shovel mounted on a hull and so arranged as to be stable under all conditions. The dipper dredge of to-day is a remarkable piece of machinery. It can raise its spuds and move in a minute's time, excavate all kinds of soil from silt



Cross-section of Ditch Excavated with Floating Dipper Dredge.
Figure 89.

to loose rock, pull stumps, remove boulders, bridges, and various other obstructions, drive piling, erect simple structures, build earthen dams, etc.

The dipper dredge can be used for the excavation of any ditch, the width of which is greater than 16 ft. There must, of course, be sufficient water to float the dredge. It is sometimes necessary during dry seasons to sink a well and pump water into a small artificial reservoir built around the dredge in order to float it. Open ditches with top width of 16 ft. and depth of 3 ft., to those having a width of 100 ft. and depth of 20 ft., have been successfully constructed by this versatile excavator. These ditches are not true or uniform in cross-section and cannot be made by a dipper dredge with smooth and continuous side slopes. The cross-section of a typical dipper dredge ditch is rounded as shown in Fig. 89. The

principal objection to the use of a floating dipper dredge is the roughness and unevenness of the ditch, and the objections to this are stated in Articles 52 and 58. However, the author has found from his experience in superintending such work that much of the roughness is unnecessary and is due to the careless operation of the dredge. After two or three years of use, with ditch running on an average one-quarter full, the cross-section will gradually take the form of a semi-circle, which is the best and most efficient form of an open channel. Such a ditch will, bowever, require considerable maintenance to remove vegetation along the side, and silt and débris from the bottom.

Under average working conditions the capacity of a $1\frac{3}{4}$-yd. dipper dredge should be about 1,250 cu. yd. for each 11-hour shift. The operating cost should average about 4 cents per cubic yard. For a $3\frac{1}{2}$-yd. dipper dredge the excavation should average about 2,000 cu. yd. at an operating cost of $5\frac{1}{2}$ cents.

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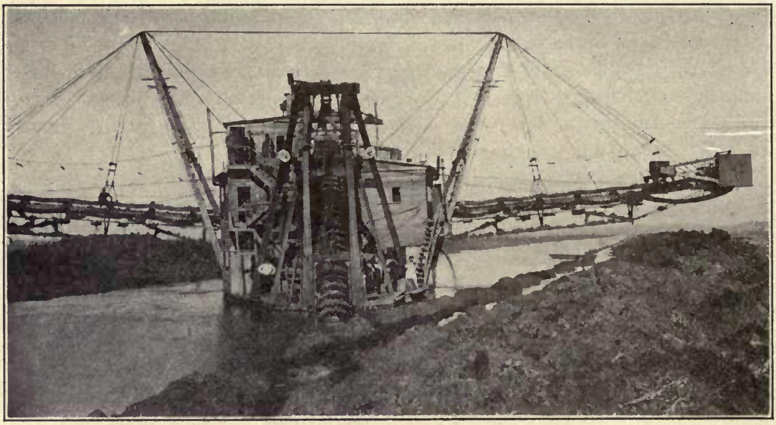
B. LADDER DREDGES

80. Field of Work.—The ladder, or elevator dredge, is a type of excavator which is very popular and has been used for many years in

England and on the Continent. However, in this country, it has been principally used for placer mining in the Northwest and in Alaska. Not until recently has this type of dredge been used in reclamation projects. The best-known examples of the use of a ladder dredge in canal construction are those on the New York State Barge Canal and the Panama Canal. During the last three years (1909–12), a ladder dredge of large capacity has been used with considerable success in the excavation of a large drainage ditch in western Iowa and also in the construction of irrigation ditches in Idaho. It is unfortunate that cost data on the use of this dredge are not available. Descriptions of ladder dredge operations on the Fox River, Wisconsin and on the New York State Barge Canal will be given later on in this chapter.

81. General Description.—The ladder, or elevator dredge, consists of a barge or hull, which supports the excavating machinery. The



Elevator Dredge Excavating Large Drainage Ditch.
Figure 91.

latter is made up of a ladder, which is a framework, carrying at each end two sheaves over which run two endless chains. Along these chains are placed buckets or scrapers at intervals of about 3 to 6 ft. each holding from 3 to 15 cu. ft. One end of the ladder is hinged to the hull and the other end is suspended from a frame placed at the bow of the hull. By means of wire rope running over sheaves, the outer end of the ladder may be raised and lowered to any desired depth. The buckets in passing around the ladder scrape the material from the bottom and front of the excavation and bring it to the upper end of the

ladder above the deck. Power is applied from an engine to a shaft, which passes through the ladder and drives the chains to which the buckets are attached. The material is automatically discharged from the buckets upon belt conveyors, which carry it to the spoil banks or to barges for removal. In some cases the excavated material falls into a hopper, where it is mixed with water and the resulting fluid mass flows through spouts or troughs to the spoil areas. The horizontal movement of the dredge is generally secured by a single spud which is placed and operated at the stern of the hull. In some ladder dredges the heel of the ladder is pivoted to the hull, so that the ladder may be rotated. However, the ladder is generally fixed to the hull and passes through a well in the bow. Fig. 91 shows a front view of a large ladder dredge in the excavation of a drainage ditch near Glencoe, Iowa.

HULL

The hull or barge is rectangular in shape and generally constructed of heavy timbers. The hull may be built as one structure with a well through the bow for the ladder, or as two structures with a space between for the operation of the ladder. The latter type of construction was used for the New York State Barge Canal dredges so that they might pass through the locks of the Erie Canal.

The size of the hull depends on the capacity of the dredge. The length, which varies from 60 to 120 ft. is generally about five and one-half times the width, which varies from 30 to 50 ft., and the depth varies from 6 to 10 ft. The draft of a completed dredge is from 4 to 6 ft. Suitable cross frames of timber or steel are used to brace the hull and heavy planking with well-calked joints forms the outer covering.

A few ladder dredges have had hulls composed of two steel pontoons, which were held parallel, at a suitable distance apart, by steel cross-frames.

LADDER

The ladder is composed of the chain of buckets and the frame upon which it revolves. The ladder frame is generally a structural steel framework or trussed wooden beam. The length of the ladder frame varies with the size and capacity of the dredge and the depth of excavation to be made. The upper end of the ladder-frame is hinged to the upper tumbler-shaft, while the lower end is suspended by heavy tackle,

from the bow gantry. The frame carries at its two ends tumblers or large metal barrels. The upper tumbler is revolved by power supplied from the main engine through a shaft, while the lower tumbler is revolved by the friction of the bucket chain.

The upper tumbler is pentagonal, while the lower tumbler is often made hexagonal. The five-sided tumbler is the most practical shape for both tumblers, as it allows three adjacent sets of links to come into contact with the tumbler at a time and with continuous operation of the chain.

CHAIN AND BUCKETS

The chain is composed of buckets, links, and the connecting pins. The chain may be arranged in two different ways, depending on the

Bucket Chain and Gantry of Ladder Dredge.
Figure 92.

material to be excavated. For hard material, the buckets are joined directly, following each other closely, as shown in Fig. 92.

For softer materials, such as would ordinarily be encountered in the excavation of drainage and irrigation ditches, the buckets are separated by a link connection, making a space between the adjacent buckets.

The buckets are generally made in three parts and riveted together. The bottom is made of a specially treated, open-hearth, basic steel casting, the sides of pressed steel and the cutting edge of manganese steel. A continuous lip or cutting edge is generally used for the excavation of soft material, while teeth are used when hard material is to be excavated.

The pins are made of steel and have a continuous bearing along the rear edge of the bucket. The outer ends of each pin are fixed by set screws in the bushings of the outer ends of the links. The buckets are fastened to the links by rivets and the whole chain is made of such strength that if the buckets encounter an obstruction that they are unable to move, the chain and machinery will be stopped. The buckets have a capacity from 3 to 13 cu. ft., the ordinary sizes being 3, 5 and $8\frac{1}{2}$ cu. ft. The movement of the buckets is slow and uniform, the chain moving at a rate of 18 to 20 buckets per minute.

GANTRY

The lower end of the ladder-frame is suspended from a gantry or inclined framework, which is placed at the bow of the hull. This gantry is generally built of heavy timbers or structural steel shapes. The framework may be made with either parallel or inclined posts. At the top of the frame are hung suitable sheaves over which run the wire cable supporting the lower end of the ladder frame. See Fig. 92. The gantry has a height of from 15 to 25 ft.

SPOIL CONVEYORS

The material contained in each bucket is automatically deposited when the bucket turns over the upper tumbler and starts on its downward path. The material either falls into a hopper or upon a moving belt. The latter type is generally used in reclamation work. The moving belt is either leather or canvas and rubber, from 2 to 4 ft. in width, and is supported on a series of small wheels, which are spaced along a light steel frame. This frame extends from the hull to each side of the ditch or canal and is supported as a cantilever, from an A-frame. See Fig. 97. Where the excavated material has to be

carried to a distance, the conveyor is often placed at the stern of the hull and a series of conveyors supported on pontoons are used. See Fig. 96.

SPUDS

One or two spuds are placed at the stern of the hull to secure stability of the dredge in operation, but principally to provide for the horizontal movement of the dredge. The spuds are generally built of a single timber with a pointed iron shoe at the lower end, and are usually operated by separate engines of the type used on floating dipper dredges as explained in Chapter VII.

ENGINES

The engines used are of the standard horizontal, double-cylinder type, as described in Chapter VII for floating dipper dredges. Independent engines are used for the operation of the bucket-line, the raising or lowering of the ladder, the operation of the spoil conveyors and operation of the spuds.

In many cases the conveyor and main engine are driven by elecrtic motors. The power is furnished from an electric generator which may be belt or direct connected to a steam engine.

A centrifugal pump, driven by a separate engine, is generally used to furnish water for a hydraulic monitor, for the hoppers (if there are any) and for perforated pipes, which extend along the sides of the belt conveyor for cleansing purposes.

Steam pumps of standard type are used to supply the condensors, feed-water heaters, and the boilers with suitable water supply.

BOILERS

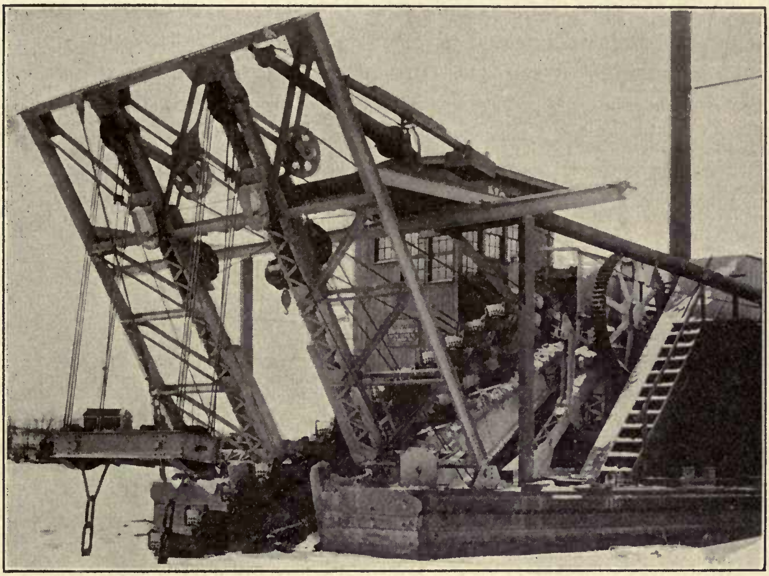
The boilers used are generally of the Scotch marine type and should be of more than estimated capacity to supply power for the various engines. The reader is advised to read the discussion of boilers in Chapters VI and VII.

81a. Use on N. Y. State Barge Canal.[1]—Two ladder dredges, named the Tornado and the Cyclone, were used during the year 1909 on the New York State Barge Canal. They were alike in construction and the conveyor systems were made interchangeable. In operation, how-

[1] Abstracted from Barge Canal Bulletin, March, 1909.

ever, the dredge Cyclone used the scow conveying system and the dredge Tornado the shore conveyor.

The dredge hulls were made in two sections so that the dredges could pass through the locks of the Erie Canal. Each section of the hull or pontoon had a length of 97 ft., a width of 17 ft., and drew 9 ft. of water. They were constructed of heavy timbers covered with planking and the sections braced together with steel truss frames. The



View of Front End of Ladder Dredge on New York State Barge Canal.
Figure 94.

sections or pontoons were flat bottomed, the bows blunt-pointed and the sterns square.

The bucket line was carried by a heavy ladder frame composed of steel-plate girders having an over-all length of 50 ft. The upper end of the frame was hinged to the upper tumbler shaft, while the lower end was suspended by means of a heavy tackle from the main or bow gantry. This is a steel framework composed of four channel posts well braced transversely. These details are well shown in Fig. 94.

The bucket line was of the close or continuous bucket system and each bucket was constructed in three parts; the bottom of an open-hearth, basic steel casting, the sides of pressed steel and the cutting

edge of manganese steel. The capacity of each bucket was $8\frac{1}{2}$ cu. ft. and its weight 2,050 lb. or practically 1 ton. The buckets and links were hinged together with 4-in. turned steel pins.

In Fig. 94, it will be noticed that a large monitor nozzle is placed above the bow of the dredge. This was used to break away and wash down material from high banks in front of the dredge. Water under high pressure was forced through this nozzle by a 12-in. centrifugal pump, direct connected to an 11-in. by 10-in. marine engine.

The main power equipment of each dredge consisted of a 100-kw. generator direct connected to a 13-in. by 16-in. horizontal, single-cylinder engine. A 12-in. centrifugal pump direct connected to a 100 h.p. double engine supplied water to the hoppers and to the jet-cleansing pipes of the belt conveyors. Two standard steam pumps, of the locomotive type of 150-h.p. each were used for boiler supply.

The dredge was swung from side to side across the channel by wire cables attached to trees along the sides of the channel and to winch drums on a 5-drum winch engine operated by a 25-h.p. electric motor.

Two spuds were located at the stern of the hull and when digging both were kept down to prevent the shoving back of the dredge. To move the dredge ahead, one spud was kept down and the hull was swung around by winding up the cable attached to the shore. Then this spud was raised and the other spud lowered and the operation repeated. The spuds were operated by a special 8-in. by $8\frac{1}{2}$-in. reversible engine of 40 h.p., which moved gearing directly attached to them.

The bucket chain moved at an average speed of 22 per minute, thus discharging 250 cu. yd. in about 26 minutes. The material passed from the bucket line at the top of the ladder frame into a hopper. A grating of heavy bars was placed over the bottom of the hopper to intercept heavy stones, limbs of trees and other large objects. The material after passing the hopper, fell upon a belt conveyor of the Robins type. This conveyor was made up of a steel framework, supporting a double-thick canvas and rubber belt, having a width of 4 ft. and a length of 60 ft. The belt was driven by a 25-h.p. electric motor and at a speed varying from 250 to 500 ft. per minute, depending on the character of the material being handled. The belt conveyor dumps the material on to a delivery scow which carries a belt conveyor 42 in. wide and extending the whole length of the scow. The belt may be raised so as to have a slope as great as 11 degrees with the horizontal. The delivery

scow was equipped with a winch, which was used for placing the dump scows, operating the spud at the stern and tipping the delivery chute. This winch was operated by a 25-h.p. electric motor.

The Tornado used the shore conveyor system. In this case, the delivery scow described above, was replaced by an intermediate scow carrying a 42-in. Robins conveyor having a length of 60 ft. This belt was driven by a 20-h.p. electric motor. Attached to the intermediate scow was a shore scow 80 ft. long and 52 ft. wide carrying a conveyor 200 ft. long. By means of this shore conveyor system, the excavated material was placed at a distance of 100 ft. inshore and to a height of 60 ft. above the ground surface. The shore conveyor was operated by a 70-h.p. electric motor.

All of the machinery of the dredge and of the conveyors was controlled by one operator, located in a small house placed near the bow and above the machinery house. Besides this operator there were required an engineer, a fireman, an oiler, and deck hand on the dredge, a man for handling and controlling the conveyor belts, and three men for handling the scows while loading. On the shore conveyor system, one man was required on the intermediate and the shore scows. The dredge Cyclone required the use of a tug and from four to six dump scows. Each scow was of the standard, bottom-dumping type, 80 ft. wide with five compartments and a capacity of 250 cu. yd. Stones up to a size of 24 in. were handled without difficulty and material of all kinds from silt to blasted hard pan and rock was excavated.

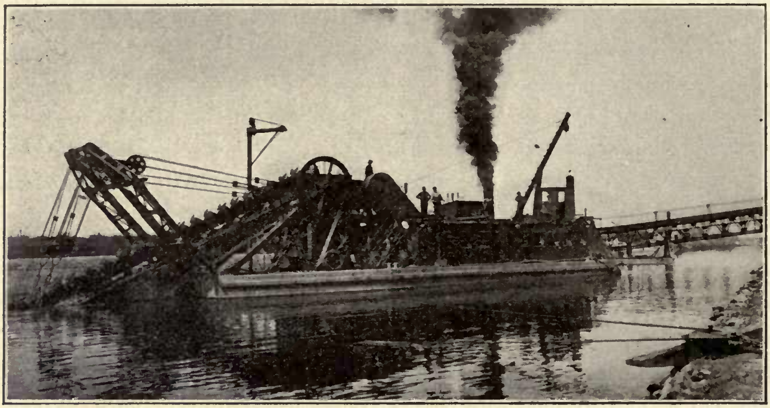
81b. Steel Pontoon Dredge, N. Y. State Barge Canal.[1]—During the four months from August 1, 1909, to December 1, 1909, a ladder dredge of standard design was operated on a section of the New York State Barge Canal, near Adams Basin. Figs. 95 and 96 show the front and rear views of this dredge.

The hull was made up of two steel pontoons, which were braced together by a rigid steel framework. The buckets were each of 5 cu. ft. capacity. The excavated material was discharged into a hopper at the top of the ladder and then on to a belt, which in turn discharged into a second hopper and on to a second belt. These belt conveyors were carried by pontoons or scows, placed at the rear of the dredge. A third belt conveyor carried the material 40 to 50 ft. on to the bank of the channel. The third pontoon was pivoted to the stern of the second pontoon. The belt conveyors were each operated by a small electric motor.

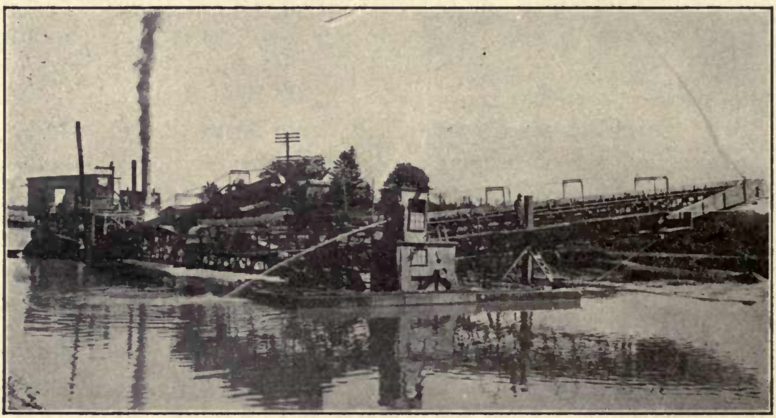
[1] Abstracted from Engineering-Contracting, Sept. 7, 1910.

The total cost of the entire dredge plant was $70,000.

Considerable difficulty was experienced in keeping the soft excavated material in place on the spoil banks. At first heavy wooden fences were built to hold the embankment to full height. But



View of Excavating End of Steel Pontoon Dredge Operating on New York State Barge Canal.
Figure 95.



View of Elevator End of Steel Pontoon Dredge Operating on New York State Barge Canal.
Figure 96.

these proved to be very expensive and inefficient and were replaced by dykes of earth and sod having a height of 4 ft. and placed along the outside edge of the embankment.

Following is given the cost of the work for the months of August, September and October, 1909:

AUGUST, 1909

Coal and oil,	$1,984.50
15 tons coal for hoisting engine @ $2.85,	42.75
Miscellaneous supplies for hoisting engine,	5.25
Miscellaneous supplies for hoisting engine and derrick,	6.48
Hauling supplies,	54.00
Crew of dredge,	2,296.68
Total cost,	$4,389.66

Total excavation, 18,638 cu. yd.
Cost of excavation; $4,389.66 ÷ 18,638 = 23.6 cents per cubic yard.
Cost of moving 6,244 cu. yd. of earth by use of scrapers, (supplementing work of dredge), $1,280.50
Cost of scraper work, 20.5 cents per cubic yard.
Cost of wooden forms and compacting and spreading 10,015 cu. yd. of excavated material, $1,193.25
Cost of forms, spreading, etc., 11.9 cents per cubic yard.

SEPTEMBER, 1909

Interest, depreciation and repairs,	$2,205.00
180 tons of coal (2 tons per shift),	513.00
150 gal. gasoline @ 12 cents,	48.00
Oil (80 gal. @ 19 cents, 60 gal. @ 35 cents,	36.20
1,200 lb. grease @ 8 cents,	96.00
200 lb. waste @ 8 cents,	16.00
Teams,	245.00
Labor,	2,827.00
Total cost,	$5,986.20

Total excavation, 32,000 cu. yd.
Cost of excavation, $5,986.20 ÷ 32,000 = 18.6 cents per cubic yard.
Total working time was 90 eight-hour shifts.
The cost of embankment was as follows:

Labor, spreading and compacting,	$3,151.50
Hauling lumber for forms,	177.16
Cost of lumber for forms,	1,125.00
General,	290.00
Labor on forms,	828.32
Hauling supplies,	55.00
Total cost,	$5,626.98

Total amount of excavated material worked, 11,000 cu. yd.
Cost of embankment; $5,626.98 ÷ 11,000 = 51.1 cents per cubic yard.

OCTOBER, 1909

Interest and depreciation,	$2,351.66
186 tons coal @ $2.85,	530.10
Labor,	3,145.58
Teams,	5.00
Oil, grease and waste,	153.09
Gasoline,	18.60
Repairs,	18.90
Total cost,	$6,222.93
Total excavation,	25,500 cu. yd.

Cost of excavation; $6,222.93 ÷ 25,500 = 24.4 cents per cubic yard.
Total working time was 93 eight-hour shifts.
The cost of embankment was as follows:

Labor, spreading and compacting,	$2,898.25
Forms,	567.50
Erection,	108.50
Hauling,	95.00
Total cost,	$3,669.25
Total amount of excavated material worked,	21,800 cu. yd.

Cost of embankment; $3,669.25 ÷ 21,800 = 16.9 cents per cubic yard.

81c. Use on Gran Canal, Mexico.—The Gran Canal, which was built during the years 1890 to 1896 by S. Pearson & Son of England, was designed to drain three lakes near the City of Mexico, Mexico. The canal had a total length of 29½ miles, a bottom width varying from 16 ft. 5 in. to 21 ft. 4 in., a depth varying from 33 ft. to 72 ft., side slopes of 1 to 1 and an average fall or grade of about 1 ft. to the mile. For the first 14 miles, the soil was a saponaceous marl for the full depth; for the last 15 miles the soil was this same material for the upper 20 ft. and below this was a hard material known as "tepetate."

Five ladder dredges excavated about 8,500,000 cu. yd. in four years. These dredges were built by Messrs. Lobnitz & Co. of Renfrew, Scotland, shipped to Mexico, where they were erected on the site of the canal. Four of the dredges were of the same size and build, while the fifth was larger and differed from the others somewhat in details of construction. The hulls of the four smaller dredges were made of iron and had a length of 120 ft., width of 40 ft. and depth of 7 ft. and each provided with a ladder well 40 ft. in length and 7 ft. in width. The hull of the larger dredge had a length of 140 ft., a width of 45 ft. and a depth of 10 ft. and was built with a ladder well, the length of which was 48 ft. and width 7 ft. The heights of the upper tumblers above the decks of the hulls were 56 ft. for the smaller dredges and 74 ft. 6 in. for larger dredge.

The ladder frames were box girders with $\frac{7}{16}$ in. thick web plates, which were cross-braced every 6 ft. with transverse webs. The upper and lower ends of the girders were provided with heavy brackets for the support of the tumbler and suspension shafts. To the web plates, on the outside, were bolted 6-in. elm timbers. The ladders were all 78 ft. in length, 4 ft. 6 in. in width and 4 ft. in depth. The top tumbler was four-sided, with outside flanges, and was keyed to a shaft 12 in. in diameter, which alone carried the drive wheel, chain connected to the main engine shaft. The bottom tumbler was six-sided, with inside and outside flanges and was keyed to an 8-in. diameter shaft. A guide wheel of special construction, having a diameter of 11 ft. and a width of 3 ft. 9 in., was placed just below the ladder frame near its center, and served as a guide to the bucket chain and also to take up the sag of the chain. The wheel was made of solid steel plates, reinforced with 6-in. timbers under the periphery of the wheel, to take the pounding of the buckets. The bucket chain carried buckets having a capacity each of 11 cu. ft. and placed 3 ft. 3 in. apart. Each bucket had a cast-steel back $\frac{1}{2}$ in. thick, a body of $\frac{5}{16}$-in. steel plate with $\frac{7}{8}$-in. malleable steel cutting edge and provided with bushings of $\frac{1}{2}$-in. wrought manganese steel in lugs. Buckets with hinged bottoms were used in sticky soil and a cam on the top tumbler was used to lift the bottoms and throw out the contents. The buckets were fastened to links made up of three steel plates riveted together and provided with $\frac{1}{2}$-in. wrought manganese steel bushings, fitted at the ends for pins. These were of wrought manganese steel $2\frac{1}{2}$ in. in diameter.

Steel chutes, extending from a hopper below the upper tumbler, carried the material to the spoil banks on both sides of the canal. These chutes were 3 ft. in diameter and were supported by wire cables from the tops of A-frames, which were placed at the sides of the hulls. The inclination of these chutes could be varied from 1 in 20, to 1 in 5, and the excavated material was carried to a distance of 165 ft. from the center of the dredge.

The main engine of each dredge was a two-crank compound engine, with a high-pressure cylinder 14 in. in diameter and a low-pressure cylinder 28 in. in diameter, the stroke being 15 in. At a speed of 100 r.p.m., the developed horse-power of each engine was 150. A pitch chain connected the main shaft of this engine to the upper tumbler shaft which, by means of gearing, was driven at a speed of 6 to 9 r.p.m.

On the four smaller dredges were also independent two-crank compound engines, with one high-pressure cylinder 9 in. in diameter and one low-pressure cylinder 14 in. in diameter with a stroke of 12 in.

The corresponding engine in the larger dredge had a high-pressure cylinder 10 in. in diameter, a low-pressure cylinder 20 in. in diameter and a stroke of 15 in. These engines were used to operate the winches, the ladder-hoist winches and the tower pumps.

The maneuvering winches were placed in the stern of each dredge and were operated by belt connections to an overhead line of shafting worked by the auxiliary engine. The ladders were raised and lowered by a chain tackle suspended from the gantry frames at the bow of the hulls. The tackle consisted of four upper and five lower iron sheaves, each 26 in. in diameter. The tower pumps were operated by a three-throw shaft. They discharged water, at a maximum rate of 600 cu. ft. per minute into the chutes, through a 12-in. pipe.

The steam was furnished by three return-tube boilers, each having a length of 10 ft. and a diameter of 7 ft. They were arranged to work independently and had a total heating surface of 408 sq. ft., a grate area of 19.6 sq. ft. and a working pressure of 75 lb. per square inch.

A hand jib crane of 2 tons capacity, was placed at the box of each dredge and was used to remove buckets, small machinery parts, etc., which had to be sent away for repairs.

As most of the excavation was carried on in two 11-hour shifts, electric generators were belt connected to the shafting and furnished light for the night shift.

The maximum monthly excavation was 124,230 cu. yd. by one dredge. In the harder soil, the average excavation was 90 cu. yd. per hour. Difficulty was experienced in keeping the dredge up to the face and prevent bumping, when excavating hard soil. Faces up to 9 ft. above the water level were dredged, but a face of 6 ft. in height was found to be the most suitable for average work.

The following table gives the relative time occupied in the various steps of operation, by each dredge:

	Soft soil	Hard soil
Repairs to machinery,	11.4	27.0
Changing buckets, links and pins,	1.7	2.9
Shifting mooring chains,	9.1	5.1
Cleaning buckets and shoots,	1.1	1.0
Sundries,	2.9	0.7
Time actually dredging,	73.8	63.3
	100.0	100.0

The actual amount of excavation for each dredge is given by the following table (No. 1 being the larger dredge and Nos. 2 to 5 inclusive, being the four smaller dredges):

No. 1 working 50 months.	2,480,250 cu. yd.
No. 2 working 48 months,	1,977,500 cu. yd.
No. 3 working 45 months,	1,533,700 cu. yd.
No. 4 working 40 months,	1,692,000 cu. yd.
No. 5 working 34 months,	824,250 cu. yd.
Total,	8,507,700 cu. yd.

For 11 months the dredges worked only during the day shift, and during the remaining time worked both during the day and night shifts.

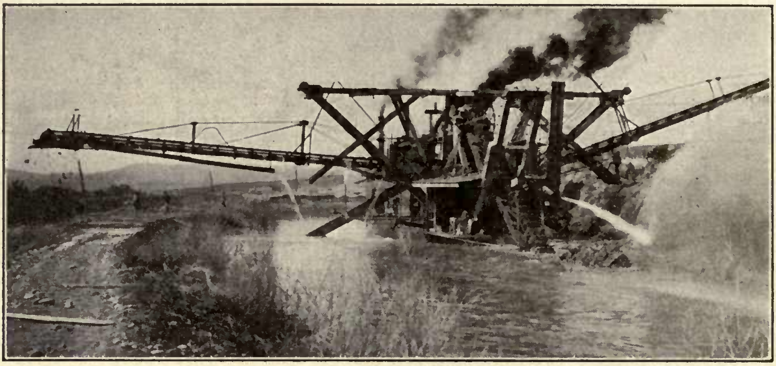
The crew of each dredge was made up as follows:

1 captain in charge of dredge.
1 mate, as first assistant to captain.
2 laddermen, in charge of repairs to ladder and bucket chain and for general repairs.
1 chief engineer, in charge of machinery.
2 assistant engineers, to operate levers and have general care of machinery.
2 oilers.
4 firemen.
16 winchmen.
2 laborers, to look after chutes.
24 laborers, on shore to look after moorings and anchors.
1 coal dredger, for special service.
4 laborers, for location of sights on shore and to take soundings.

81d. Use in Washington.—The U. S. Reclamation Service has used a Bucyrus ladder dredge on the enlargement of the Main Canal of the Sunnyside Project near Sunnyside, Washington. The excavation extended from mile 0.228 to mile 20.67—making a total length of canal dredged of 20.342 miles. The average distance of the work from a railroad station was 2 miles.

The work was carried on in two shifts from December 1, 1909, to June 19, 1910, and in three shifts per day from June 19, 1910, to October 1, 1911. The character of the material excavated varied from loose gravel to hard pan. At about mile 1, the material was so hard that explosives were necessary to assist the hydraulic giant in breaking down the high banks. Blasting was carried on from this point to the end of the work. From mile 13 to mile 20.67, teams were employed to excavate the high banks above the water line. Difficulty was experienced in disposing of the excavated material where the banks were high. On fills and shallow cuts bulkheads were built along the right-of-way on the lower bank to keep the wet material from flowing into adjoining fields. In winter, ice hindered the progress of the work to a considerable extent.

The dredge used was a Bucyrus ladder dredge equipped with steam-power and a $3\frac{1}{2}$-cu. ft. continuous bucket chain. The hull was built



Elevator Dredge Excavating Large Irrigation Canal.
Figure 97.

View of Excavating End of Ladder Dredge on Irrigation Work in Washington.
Figure 98.

of timber with a length of 82 ft., a width of 30 ft., a depth of 6 ft. 6 in. and drew 5 ft. of water. Steam was furnished by two locomotive

type boilers, 44 in. in diameter and 18 ft. long and having a rated capacity of 80 h.p. The main drive and ladder hoist were driven by an 8-in. by 12-in. double horizontal engine of 70 h.p. The winch machinery for operating the spuds and swinging the dredge was driven by a two-cylinder 6-in. by 6-in., double horizontal engine of 20 h.p. The belt conveyors were operated by two 7-in. by 10-in. single-cylinder, center-crank, horizontal engines of 18 h.p. A No. 1 Hendy hydraulic giant was mounted on the bow of the dredge and water was forced through it by a two-stage, 6-in centrifugal pump belted to a 10-in. by 12-in. single-cylinder upright engine of 80 h.p. This giant or monitor was used to remove banks above the water level and beyond the reach of the buckets. Two belt conveyors, one on each side of the dredge, were used for the disposal of the excavated material. Each conveyor was 72 ft. long and consisted of a steel framework supporting a 7-ply 32-in, rubber conveying belt. Fig. 97 shows the dredge in operation with a high bank on one side. A near view of the bow showing the details of construction is given in Fig. 98.

The operating force consisted of eight men and four horses. The following scale of wages was paid:

Superintendent,	per day,	$7.50
Operator,	per day,	5.00
Engineer,	per day,	4.67
Spudman,	per day,	3.83
Fireman,	per day,	3.33
Oiler,	per day,	3.00
Deckman,	per day,	2.50
Man and team,	per day,	4.50

TABLE XXII

COST OF CANAL EXCAVATION WITH LADDER DREDGE

Item	Total excavation	Total cost	Cost per cu. yd.
Excavation	929,723 cu. yd.		
Labor, dredge		$26,960.63	$0.029
Labor, spoil banks		31,159.06	0.034
Fuel		33,043.07	0.036
Plant maintenance		52,327.40	0.057
Plant depreciation		41,432.53	0.045
Total		$184,922.69	$0.201
Engineering and administration		28,154.41	0.031
Grand total		$213,077.10	$0.232

The maximum excavation per eight-hour shift was 1,429 cu. yd.

The average excavation per eight-hour shift was 557.9 cu. yd.

The maximum excavation per week was 17,644 cu. yd. for the week ending June 28, 1911, working three eight-hour shifts.

The average excavation per actual working hour was 128.7 cu. yd. The per cent. of lost time was 49, made-up of moving as 10 per cent. and of repairs and miscellaneous as 39 per cent.

81e. Use on Fox River, Wisconsin.[1]—A ladder dredge, built by the Bucyrus Company of South Milwaukee, Wis., was used by the U. S. Government for dredging of the channel of the Fox River in

Ladder Dredge operating on Fox River, Wisconsin.
Figure 99.

Wisconsin. The plant consisted of a dredge with two intermediate and one delivery scow, which were operated either in line or without the use of one or both of the intermediate scows. Fig. 99 gives a general view of the plant in operation.

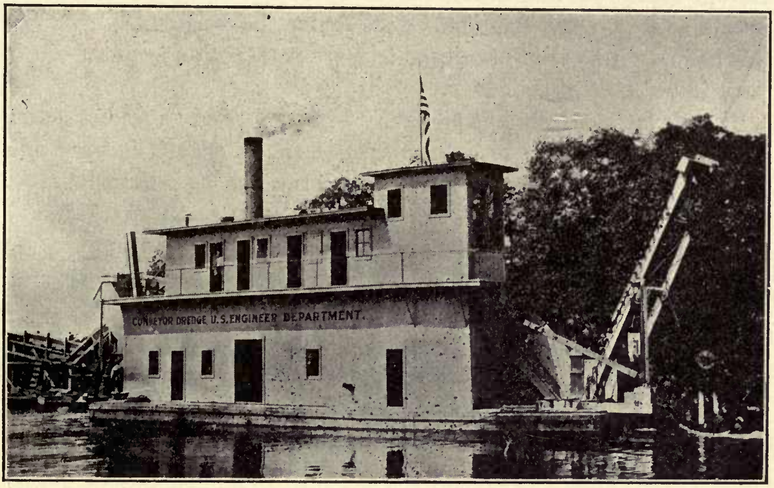
The dredge was a regular elevator dredge, equipped with a chain of 39 buckets of 5-ft. capacity each. The buckets were provided with steel teeth, and excavated hard material up to a depth of 10 ft. One stern spud provided a pivot about which the dredge could swing through a radius of 80 ft. and covering a channel width of 145 ft.

The bucket chain was driven by a 9-in by 12-in double reversing engine, by gearing, which also operated the ladder hoist. A six-drum winch, driven by a 6-in. by 6-in. double-cylinder engine, was used to operate the anchor, spud lines, etc. A walking spud operated by a steam cylinder was used to move the dredge. The belt conveyors on the dredge and the scows were operated by elec-

[1] Abstracted from Engineering News, October 25, 1906.

tric motors supplied with current from a 35-kw. electric generator, driven by a 10-in. by 10-in. engine on the dredge. This generator also supplied current for lighting the plant and power to a 6-in. spray pump for cleaning the belts. Steam was furnished by a Scotch-marine boiler 9 ft. in diameter and 10 ft. in length, water-back type and equipped with two Adamson furnaces 35 in. in diameter. The delivery scow was provided with a winch operated by an electric motor and used for operating the anchor lines, gantry and spud.

The hulls were built of Oregon fir and strongly braced and bolted together. The dredge was 75 ft. long, 31 ft. wide and 6 ft. deep.



View of Excavating End of Elevator Dredge on Fox River, Wisconsin.
Figure 100.

Quarters for the crew were provided on the upper deck, where the pilot house was also located, whence the operator had complete control of the operation of the plant and from which a view of the whole work was afforded. Fig. 100 offers a general view of the dredge.

The intermediate scows were 40 ft. long, 16 ft. wide and 3 ft deep, each carrying a belt conveyor 65 ft. long. The delivery scow was trapezoidal in shape, having a length of 31 ft. 4 in., 16 ft. 4 in. wide and 2 ft. deep at the receiving end and 33 ft. 4 in. wide and 4 ft. deep

at the delivery end. The hull was given this shape so as to support the overhanging load of the delivery conveyor and to secure a greater angle of gyration when the scow is attached to the dredge.

The capacity of the dredge averaged 200 cu. yd. per hour in tough clay and hard pan under adverse conditions. The preliminary test showed a capacity of 400 cu. yd. per hour in ordinary soil under favorable conditions. Most of the water raised by the buckets was lost on the conveyors and the excavated material was deposited along the banks in a nearly solid condition. The crew of the plant consisted of nine men and the cost of operation averaged about $30 per day.

82. Résumé.—The elevator dredge has been universally used in Europe for harbor and canal excavation and was largely used on the Suez Canal and the Panama Canal under the French régimé. In this country it has not been used to a great extent on account of the large initial cost of the plant.

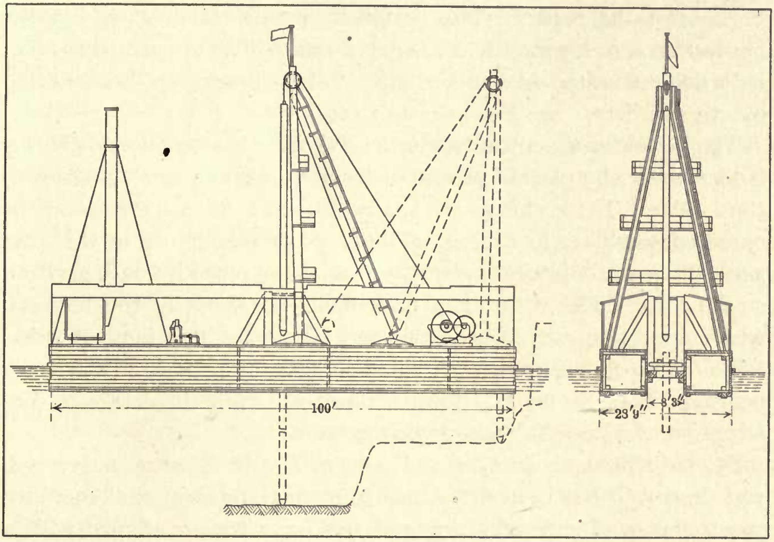
The elevator dredge has generally been regarded as an excavator for soft material, but recent experience shows that it is very efficient in the excavation of hard materials, such as indurated clay, cemented gravel, hard pan and the softer stratified rocks. Where the dredge has width of channel sufficient to breast from side to side, it can work to advantage. But where the channel is restricted as in the smaller canals or ditches, the dipper dredge is the more useful. The elevator dredge is most efficient in large canal, river, and harbor work, where there are broad reaches and a large amount of hard material to be removed.

The elevator dredge cannot be used economically on the excavation of ditches and canals for irrigation and drainage systems. These channels are generally too narrow for a dredge of this type to properly maneuver. Where the banks are high, difficulty is experienced in depositing the material. When the banks are low, dykes or bulkheads must be erected to prevent the soft material from running back into the channel or over adjacent land. Usually the sides of the channel must be sloped and this requires the raising and lowering of the bucket chain as the machine is breasting over the portion to be sloped. The deposition of the excavated material in uniform spoil banks along the sides of the channel is not easily done with a ladder dredge. The material is too wet to remain in place and the belt conveyors are troublesome to adjust and keep in good running condition.

As elevator dredges are built to meet special conditions, it is im-

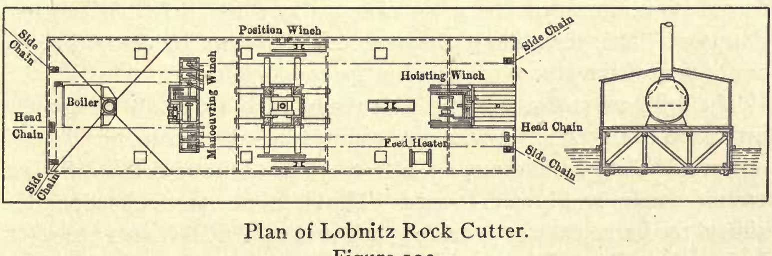
possible to give any definite rules as regards their capacities and cost of operation.

84. Lobnitz Rock Excavator.—For the excavation of rock and



Side Elevation and Cross-section of Lobnitz Rock Cutter.
Figure 101.

hard pan, it is necessary to break up the material before the ladder dredge can remove it. Blasting has generally been resorted to, but in recent years a rock cutter has been used. This cutter was



Plan of Lobnitz Rock Cutter.
Figure 102.

invented and is made by Messrs. Lobnitz & Co., Ltd., of Renfrew, Scotland.

The Lobnitz rock cutter consists of a heavy chisel of steel, weighing

from 4 to 15 tons and provided with a hardened steel, cutting point. The chisel is raised to a height of from 5 to 10 ft. and then allowed to fall vertically upon the surface of the hard material, which is thereby splintered and disintegrated sufficiently to permit its removal by the buckets of the ladder. The cutter is capable of breaking up the hardest rock in layers 3 ft. thick, at a time. The apparatus is often separately mounted on a hull, composed of two barges rigidly connected by cross girders. See Figs. 101 and 102.

The Lobnitz rock cutter has been used directly in connection with a ladder dredge by placing several picks or chisels in a well alongside of the ladder. These chisels are spaced about 2 ft. apart and can be operated singly or in unison. The picks or chisels are in this case generally made of heavy timbers, iron shod and provided with hardend steel points. The rock when broken up is raised by the buckets, which are made especially heavy and strong for this kind of work. With a 10-pick ladder dredge, an excavation of 43 tons of hard rock per hour, has been made. Figs. 101 and 102 show the details of construction of a Lobnitz rock-cutting machine.

85. **Drill Boats.**—The Lobnitz rock drill with its slow-acting well and drop drill has been found not competent to meet the American requirements of a great lifting and striking power combined with a large number of blows. Hence, the manufacturers of this country have devised the steam-actuated percussion drills with the drill steel forming an extension of the piston rod.

The drill boat consists of a barge or scow with a spud at each corner to support it upon the rock, which is being drilled. These four spuds or columns are each operated by a pair of independent engines geared to a rack on each spud. When the drills are working these spuds are forced down until the barge is raised above the height of normal flotation. This elevation of the barge is maintained by the automatic regulation of the steam pressure in the spud engines.

The drills are steam-operated percussion drills, similar in design and operation to the ordinary steam or compressed-air operated drills used on land. The piston diameter is from $5\frac{1}{2}$ to $6\frac{1}{2}$ in. and the drills are mounted on movable steel towers. The latter run on tracks along the side of the barge and are provided with vertical guides from 15 to 30 ft. in length. The drills may be raised or lowered along these guides. The feed of the drill is controlled by hydraulic plungers having a stroke the length of the guides and moved by long screws operated by small steam engines. The towers are moved along the tracks by steam or hydraulic power.

In tidal waters or streams where the water level is continually changing and of large range, the steel towers are replaced by a steel column which rests directly on the surface of the rock. This column carries the drill and its mechanism and is held in position by guides which permit of the vertical motion of the barge as the water level changes. The guides are carried on a track along the side of the barge. This construction makes the drill independent of any motion of the barge.

85a. Use on St. Lawrence River, Canada.[1]—A drill boat was used in the excavation of a ship channel through the Galops Rapids of the St. Lawrence River.

The work consisted in the removal of a very hard limestone rock in strata of from 20 to 30 in. thick, by submarine drilling and blasting, to form a channel 200 ft. wide and 17 ft. deep. The Rapids have a current of from 8 to 12 miles an hour and form an area of turbulent water, full of strong eddies, across currents and breakers. The shoal water was drilled to a length of 1,800 ft.

The drill boat carried four 5-in. drills and was supported by four 20-in. by 20-in. power controlled spuds and gear. Drums operated five $1\frac{1}{4}$-in. breasting chains, one leading upstream and two over each side. Each chain was attached to an anchor weighing about a ton. This chain weighed 84 lb. per fathom and tested to 44 tons breaking load.

The drilling was done through four slots, each 20 ft. long and 18 in. wide and located in the forward part of the barge. The drill frames carrying the steel drill spuds with pipe guides for the drill bars, were arranged to be moved the length of the wells. This allowed each drill to make a number of holes at each set-up of the barge. Holes were drilled and blasted in groups of four. The rock was drilled below grade to a depth equal to half the distance the holes were apart, the maximum spacing being 6 ft. on centers. The weight of dynamite used was equivalent to 1 lb. of nitro-glycerine per cubic yard of rock, measuring from the bottom of the hole. This rule produced uniformly satisfactory results. Allowance was made for the payment for excavation below the specified grade line, as it was impossible to perform accurate work under the unusually severe conditions. The amount of the excavation paid for below grade was 25 per cent. of the total.

The monthly cost of operation is given in the following table:

[1] Abstracted from Engineering-Contracting, April 24, 1912.

Labor:

1 captain,	$100.00	
4 drillers, @ $75,	300.00	
4 helpers, @ $30,	120.00	
1 fireman,	30.00	
1 machinist,	65.00	
1 blacksmith,	70.00	
1 helper,	30.00	
1 blaster,	60.00	
1 helper,	35.00	
1 cook,	30.00	
Total labor,		$840.00

Board and Lodging:

16 men @ $12,		$192.00

Fuel and Supplies:

60 tons of coal @ $4,	$240.00	
Oil and waste,	40.00	
Blacksmith's coal,	15.00	
Steel, iron and supplies,	52.00	
Total fuel and supplies,		$347.00
Grand total,		$1,379.00

Cost of drilling, $1.105 per drill hour.
Cost of drilling, $0.049 per foot drilled.
Average depth of drilling per hour, 2.25 ft.
Depth of drilling varied from 0 to 11 ft.

85b. Use in New York.—The following table gives a statement of the use of two drill boats in submarine rock removal in Black Rock Harbor, Buffalo, New York. This work has been in progress for several years and the drill boats were of the very latest design and of first-class construction. The boats each were equipped with five $6\frac{1}{2}$-in. Ingersoll-Rand Drills. The drill holes averaged 9 ft. 9 in. in depth.

Cubic yards drilled and blasted, 14,450
Linear feet drilled, 15,224
Linear feet per shift of 11 hours, 293
Cubic yards per shift, 278

Cost of dynamite per cubic yard,	19.5 cents.
Cost of drilling and blasting per cubic yard,	42.43 cents.
Interest and depreciation @ 2 per cent. per month on plant value, $40,000, per cubic yard,	5.94 cents.
Total cost including depreciation, etc.,	67.87 cents.

For drill holes having average depth of 3 ft. 6 in.	
Cubic yards drilled and blasted, 333	
Linear feet drilled, 3,480	
Linear feet drilled per shaft, 154.5	
Cubic yards per shift, 148	
Cost of dynamite per cubic yard,	36.1 cents.
Cost of drilling and blasting per cubic yard,	45.33 cents.
Interest and depreciation @ 2 per cent. per month on plant value of $40,000, per cubic yard,	10.40 cents.
Total cost,	91.83 cents.

86. Résumé.—The two types of rock crushers are very efficient for submarine-rock drilling and compare very favorably with drilling on land.

The Lobnitz cutter was originally used in connection with a ladder dredge for the removal of the excavated material. Recently the cutter is generally mounted on an independent hull and the loosened rock raised by a ladder or dipper dredge.

The Lobnitz cutter works most efficiently in shallow cuttings of stratified, easily shattered rock. The drill boat of the American type reaches its highest efficiency in the drilling of hard rock to depths greater than 3 ft.

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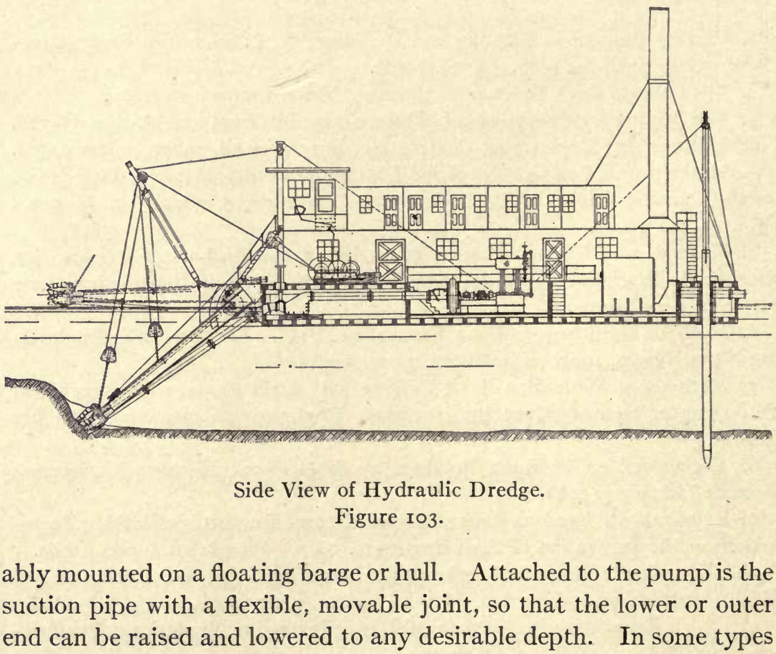
C. HYDRAULIC OR SUCTION DREDGES

90. Field of Work.—In recent years, the vast improvements in the rivers and harbors of this country have led to the development of the hydraulic dredge. The reclamation of the great tidal marshes and the removal of sand bars along the Atlantic and Pacific Coasts and the cleaning out of channels in the Mississippi River are being constantly carried on by large dredges, which are largely under government supervision. The best field for this type of dredge is the removal of soft material such as sand, silt and loose clay. It does not work well in hard material or where there are stumps, stones, logs or similar obstructions.

91. General Description.—The essential parts of a hydraulic dredge are a centrifugal pump and the power to drive it, all of which are suit-



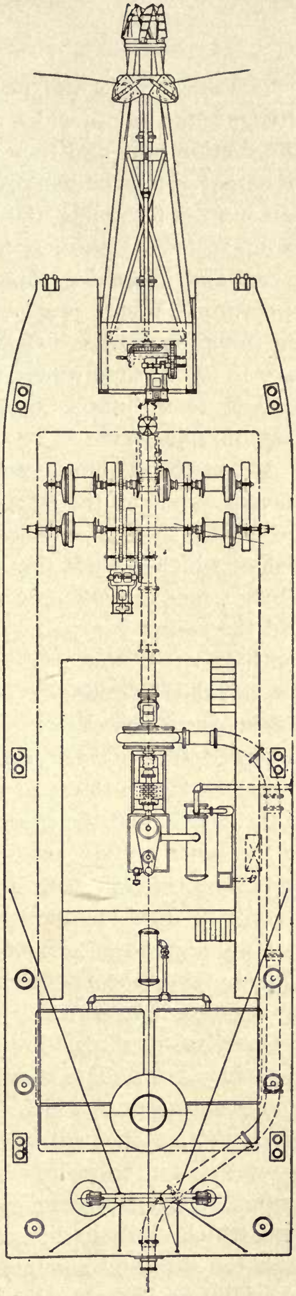
Side View of Hydraulic Dredge.
Figure 103.

ably mounted on a floating barge or hull. Attached to the pump is the suction pipe with a flexible, movable joint, so that the lower or outer end can be raised and lowered to any desirable depth. In some types of dredges a horizontal range is secured by swinging the hull of the

dredge from side to side by means of lines attached to shore anchors. In the Von Schmidt type of hydraulic dredge, the suction pipe which extends from the end of the hull is placed on a table which rotates on a circular track. By rotating the table the suction pipe may be revolved through an angle of 120 degrees. The pipe is made of wrought iron or steel, in sections which can be telescoped; the lower and smaller sections sliding up into the upper and larger ones. At the lower end of the suction pipe is placed the mouth pipe, which consists of a circular hood. On the periphery of this hood are generally placed a series of knives, which form a revolving cutter. This is made to revolve by a shaft and gearing as shown in Figs. 109 and 111.

By use of the cutter the material to be excavated is loosened up and disintegrated and by dilution with the water is readily sucked up by the pump, through the suction pipe. The cutters thus allow the use of this type of dredge in the excavation of a very stiff or hard clay. A water jet has in some cases been used to remove and dissolve the material at the end of the suction pipe, but this detail has recently been chiefly supplanted by the revolving cutter.

Figures 103 and 104 show the detail design of a standard 15- to 16-in. hydraulic dredge made by the Norbom Engineering Company of Philadelphia, Pa.



Plan of Hydraulic Dredge.
Figure 104.

PUMP

The most important element in the construction of a hydraulic dredge is the pump, which draws the excavated material up through the suction pipe and then discharges it through the discharge pipe to barges or to spoil banks on the shore. The pump is the governing factor in determining the efficiency of a dredge. The centrifugal pump is used exclusively for this work on account of its being of a rough and adaptable type of construction and range and ease of operation. Where large quantities of solid material pass through the pump (as high as 70 per cent. solids are often pumped) it is necessary to use a pump which does not require close adjustment of parts and where the parts are few in number, simple in operation and easy of replacement.

A centrifugal pump consists of a shell of circular form with two apertures, one on the periphery, the other at the center of one side. Inside this shell or outer casing revolves a set of vanes mounted on a shaft which extends transversely through the center of the casing. These vanes are the only part of the pump subject to great wear and the casing is generally constructed in two sections so that the top half can be removed and the shaft and runner taken out. In the so-called Edwards Cataract Pump, provision is made for the repair of the runner in the following manner. The vanes are made in two parts; the inner section, which is made as a part of the shaft and extends two-thirds of the distance from the shaft to the inside of the casing, and the outer section, which is a piece of metal bolted to the inner section and forming an extension to the vane. The bolts pass through slots in the extension plate and this allows the plate to be forced to one side or bent away from a heavy body (such as a stone or piece of metal) which may come in contact with it. This prevents the breakage of the runner as a whole. The plates are made of light iron and can be easily replaced at a small cost by the removal of a hand-hole cover on the casing and the bolting on of a new plate. The opening in the periphery of the casing is the admission orifice to which the suction pipe is attached and through which the material enters to the casing. The steel suction pipe is generally 15 in. to 30 in. in diameter and varies in length from 10 to 60 ft. To the side opening of the casing is attached the discharge pipe, which varies in diameter from 6 to 48 in. The following table gives the sizes and nominal capacities of a type of centrifugal pump especially made for dredging.

TABLE XXIII

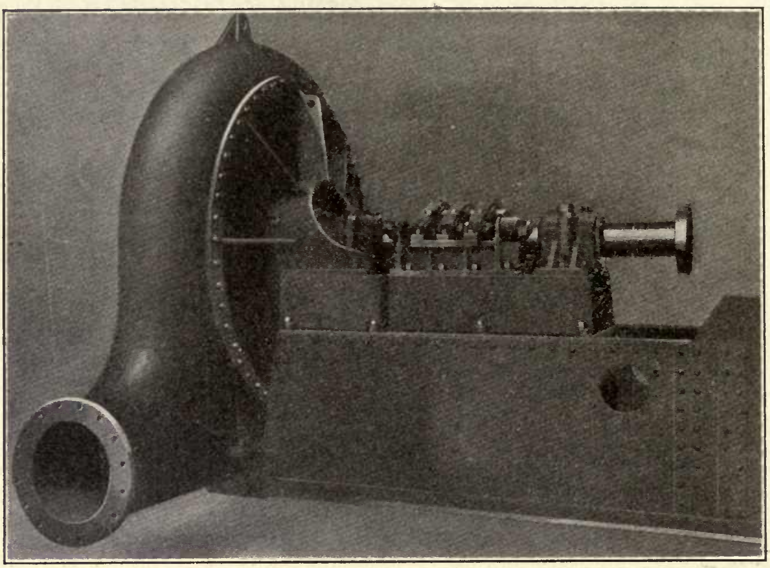
SIZES OF CENTRIFUGAL PUMPS

Diameter of discharge, inches	Capacity, gallons per minute	Capacity, cubic feet per second	Horse-power required for each foot of total head
6	880	1.965	0.446
8	1,565	3.495	0.794
10	2,450	5.45	1.192
12	3,525	7.85	1.655
15	5,500	12.25	2.49
18	7,920	17.65	3.47
20	9,780	21.8	4.14
24	14,100	31.4	5.75
30	22,000	49.0	8.71
36	31,700	70.7	12.18
42	43,200	96.2	16.10
48	56,350	125.5	20.45

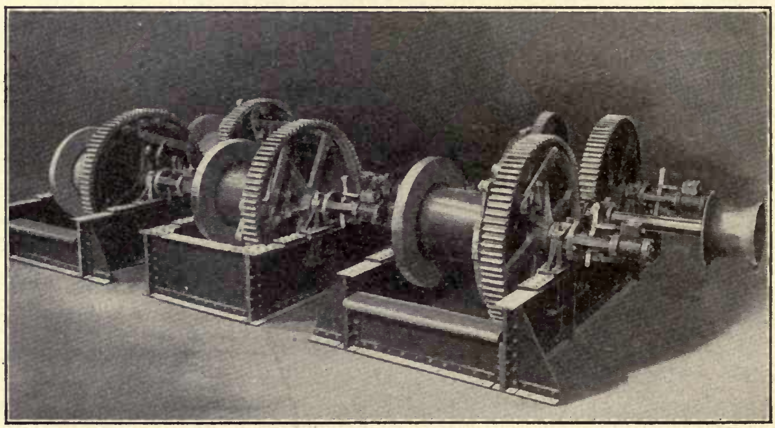
The above capacities and horse-power are based upon a velocity of discharge of 10 ft. per second. For other velocities the capacities would be in proportion. Fig. 105 shows a 20-in. centrifugal pump of the type used on the hydraulic dredges operating on the New York State Barge Canal.

ENGINES

The pump of a hydraulic dredge is generally direct connected to a steam engine of the vertical, marine type. For the small sizes and capacities compound engines are used, but where the engines are designed for hard service and to operate against high heads, the triple-expansion type is used. All marine engines for pumping service should be in excess of the requirements. They should be provided with extra large bearing surfaces and with an automatic sight-feed oil service which will allow for continuous operation. The crank shaft should be forged out of one piece of steel and especial care taken in the welding of the vanes at their junction with the shaft. The size and constructional details of the engine used depend on the size of the dredge and the work to be done. Further detailed information concerning engines, as well as the other parts of a hydraulic dredge will be given later in the descriptions of some hydraulic dredges and their work.



Centrifugal Pump of Hydraulic Dredge.
Figure 105.



Machinery of Hydraulic Dredge.
Figure 106.

Figure 106 shows the winch machinery of a 20-in. Bucyrus hydraulic dredge, used for hoisting the spuds, raising the ladder, swinging the dredge, etc.

HULL

The hull of a hydraulic dredge is rectangular in shape and with a length of about 3½ times the width. The draft is made as small as possible and generally varies from 3 to 9 ft. This requires a depth of hull varying from 6 to 15 ft. The size of the hull depends on the capacity of the dredge. The hulls are constructed of both steel and wood, but experience has shown that steel is preferable on account of its greater strength, less cost of maintenance, and its ability to withstand the pounding and vibratory strains of the machinery. Cross frames of steel or wood are spaced from 1½ to 2½ ft. on centers and connect the keelsons and deck beams. The framework is covered with steel plates or heavy wooden planking. The machinery is generally placed on a lower deck, while a superstructure or deck house extends over the greater part of the length and contains the living quarters for the crew and the operating house at the forward end.

SPUD FRAME

At the stern is placed a trapezoidal-shaped frame which suspends two vertical spuds by means of sheaves and cables leading to the engine drums. The spuds are generally single timbers of Douglas fir, long leaf pine or oak and are of sufficient length to reach the bottom of the excavation during high water.

BOILER

The prime mover is either steam or electricity. Steam is generated by boilers usually of the Scotch marine type. Where electricity is used the power is supplied either from a steam engine or from a power station independent of the dredge. The latter method of operation is the more economical and the more convenient to use when the dredge is operating near a steam or hydro-electric power plant.

DISCHARGE PIPE

The discharge pipe line extends from the pump through the stern of the hull and consists of iron or steel pipe varying in diameter from 12 to 48 in. The pipe is supported on wooden or steel pontoons, and the adjacent sections of pipe are connected by heavy rubber sleeves

fitting over the bell-shaped ends of the pipe. In recently built dredges, the joints of the discharge pipe have been formed into an iron ball-and-socket joint. Longitudinal and lateral stresses are controlled and relieved by steel springs, arranged somewhat as in the draft rigging of railway cars. Fig. 110 shows a discharge pipe of a dredge operating on the New York Barge Canal.

In order to give the reader a clearer idea of the detailed construction of hydraulic dredges, which have been used in canal excavation, the following descriptions of dredges used recently on the N. Y. State Barge Canal and for the reclamation of land in Lincoln Park, Chicago, Illinois, are offered. Space in this chapter does not allow of descriptions of other dredges which are of especial interest and have been highly successful in river and harbor work. The reader is urged to read carefully the exhaustive paper by Mr. J. A. Ockerson on "Dredges and Dredging on the Mississippi River," contained in the Transactions of the American Society of Civil Engineers, Vol. XL (December, 1898). A condensed résumé of this valuable paper is given in Engineering News, Vol. XL, No. 15 (October 13, 1898).

91a. Use on New York State Barge Canal.—During 1907 and 1908 two hydraulic dredges were in operation near Oneida Lake, New York,

Cutter and Suction Pipe of Hydraulic Dredge.
Figure 107.

in the construction of a section of the New York State Barge Canal. These dredges were the "Oneida" and the "Geyser" and each will be

described separately as each contained many individual and peculiar details, although they were both very similar in general design.

The "Geyser" was provided with a hull having a length of 96 ft., width of 29 ft., and drew 9 ft. of water. The dredge was so constructed as to excavate material to a depth of 19 ft. below the water surface and discharge the excavated material through the pontoon pipes, at a distance of 1,500 ft. and to a shore elevation of 25 ft. above water.

At the bow of the boat a steel frame of trapezoidal shape supported the suction pipe and cutter head, the driving shaft and gearing. See Fig. 107. The steel girder was 33 ft. long and was pivoted at the inner end on one side of the elbow of the suction pipe and on the other side by a hollow pivot through which the cutter-shaft is driven by a counter-shaft geared to a 65-h.p. engine with double 10-in. by 12-in. cylinders.

The pump used was a 20-in. centrifugal, direct connected to a triple expansion engine of 450 nominal horse-power, which developed on occasions 550 h.p. on overload. The pump and engine were placed near the center of the hull. The steel discharge pipe was 20 in. in diameter and passed back on the port side to the stern of the boat, where a valve was placed to prevent backing up of the material. The pipe was in 32-ft. sections and was supported on pontoons, which were heavy water-tight casks. Heavy rubber sleeves were used to connect the ends of the sections of pipe.

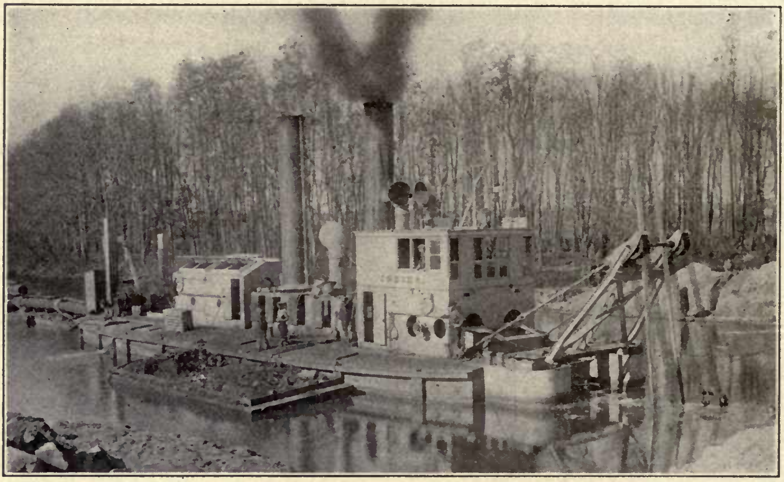
The boiler plant consisted of two B. & W. water-tube boilers, having a rated horse-power of 230, and used at about 160-lb. pressure. One duplex pump furnished water under pressure to the pump stuffing box and cutter-head bearing. Two other duplex pumps were used to supply the boilers directly or through a 400-h.p. feed-water heater. The pumps were arranged to take suction either from cold water or the hot well, as did the injectors, one of which was used with each boiler.

Electric current was supplied by a 6-kw. electric generator and furnished light for night work.

The hoisting engine was provided with five drums and was operated by a double-cylinder engine of 45 h.p. Upon the forward shaft, the drums on each side swung the dredge and the center drum raised or lowered the suction ladder or boom. The two rear drums operated the two spuds at the stern of the hull. A winch head was placed at each side of the deck for mooring purposes. The pilot or operating house was placed directly over the engine and the operator by means of 12 levers had complete control of the hoisting and lowering of the ladder and the spuds, the swinging of the dredge and the speed of the cutter.

[1]The "Oneida" excavated that section of the New York State Barge Canal commencing at the junction of Fish Creek and Oneida Lake and following the creek valley for a distance of about 5 miles.

The material excavated was a loose sandy loam and in many places large quantities of quicksand were encountered. The depth of excavation at Oneida Lake was about 15 ft. and gradually increased to 25 ft. at the eastern end of the section.



Hydraulic Dredge Operating on New York State Barge Canal.
Figure 108.

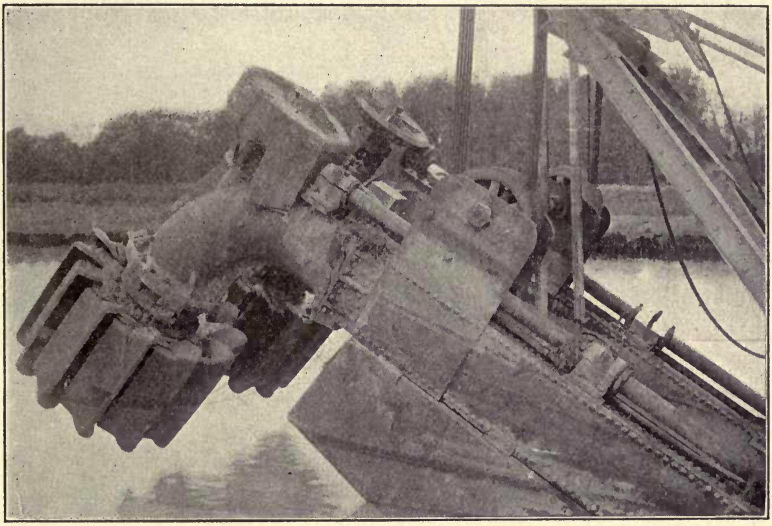
The dredge was one of two constructed by the New York Shipbuilding Company of Camden, N. J., for the Empire Engineering Corporation, which executed two contracts on the canal with these two excavators. See Fig. 108.

The hull of the dredge was constructed of steel and had an overall length of 97 ft., beam width of 17.5 ft., molded depth to deck of 10 ft., and draft of 5.5 ft. The general shape of the hull was that of a huge rectangular box with the bilges rounded off. The frames were of 3-in. by 3-in. by $\frac{5}{16}$-in. angles, in one piece from keel to deck and spaced 21 in. c. to c. The reverse frames were of $2\frac{1}{4}$-in. by $2\frac{1}{4}$-in. by $\frac{1}{4}$-in. angles and followed the tops of the 10 by $\frac{3}{8}$-in. floor plates, every alternate one extending to the deck and the intermediate one extending to the lower stringers. The deck beams were $4\frac{1}{2}$-in. by 3-in. by $\frac{3}{8}$-in. angles; one attached to each frame and crowned 3 in. in

[1]Quoted from Engineering News, December, 5, 1907.

the center of the vessel. The center keelson extended the full length of the hull and intercostal keelsons were used at the main engine foundations, where the hull was very strongly braced. The covering of the hull was steel plates $\frac{5}{8}$ in. thick.

The suction pipes were two in number and were made of steel plates and angles having a bearing on their upper sides for the cutter-shafts. The interior diameter of these pipes was $19\frac{1}{4}$ in., thus giving an area of 291 sq. in. The suction pipes extended from the centrifugal pump to the cutters at the outer ends. The steel plate, intermediate lengths of suction pipes, were connected to the pump by cast-iron breech pipes bolted to the pump and joined the pipes by heavy steel



Cutter Heads and Suction Pipes of Hydraulic Dredge Operating on New York State Barge Canal.
Figure 109.

angle flanges. The breech pipes were connected at their forward ends to two Bates curved telescopic joints, the movable interior portions of which were bolted to the upper end of the ladders. These ladders were suspended by means of heavy brackets from trunnions, the axes of which were those of the telescopic joints. The cutter heads were mounted around and concentrically with the ends of the suction pipes and were 5.5 ft. in diameter and $3\frac{2}{3}$ ft. in height. Each cutter was composed of 12 knives of manganese steel, $\frac{7}{8}$ in. thick.

The cutters and ladders were raised and lowered by two sets of blocks having five sheaves in each block and using $\frac{3}{8}$-in. wire rope. The power to operate the ladders was furnished by two independent, compound, vertical, reversing engines of 100 h.p. each. These engines were located back to back in the forward engine room. In the same engine room were located a service pump, electric light plant and blower engine. The service pump was used as an auxiliary feed pump and discharged to the boilers, ladder and cutter-head bearings, fire service pipes and over board. On the supply of suction heads, it was connected to the hot well, canal, bilges and settling tank. Fig. 109 shows the cutters.

The centrifugal pump was located in the after engine room and was provided with two suctions having a diameter of $19\frac{1}{4}$ in. and a discharge of 26 in. diameter. The casing of the pump was made in five pieces; a throat piece containing a steel knife, two upper and two lower segments. The runner was of cast steel and had a diameter of $6\frac{1}{2}$ ft.

The pump was direct connected to a triple-expansion engine which developed 750 h.p. at a speed of 165 r.p.m., cutting off steam in the H. P. cylinder at about $\frac{6}{10}$ of the stroke. The H. P. cylinder had a diameter of 17 in., the I. P. cylinder a diameter of 25 in. and the L. P. cylinder a diameter of 42 in. The average stroke was 24 in.

A separate engine was used to operate the two spuds at the stern of the hull. This engine was of the horizontal type with two cylinders $6\frac{1}{2}\times 8$ in.

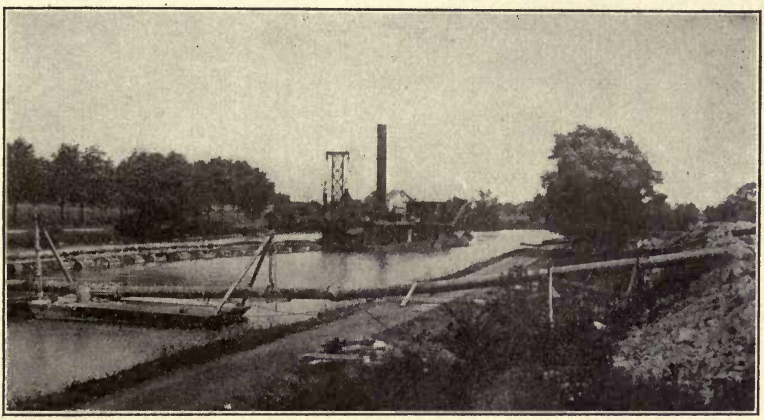
Steam was supplied from two standard water-tube boilers, working at 200-lb. pressure and having a combined heating surface of 3,750 sq. ft. and a grate area of 95 sq. ft. The engine was compound geared and provided with reverse link motion. The drums were 18 in. in diameter and were controlled by a friction hand brake. Flat cables, $3\times\frac{3}{8}$ in. were used and these were run at a speed of 40 ft. per minute.

On the forward deck of the dredge was placed a two-cylinder steam winch with $8\frac{1}{4}\times 10$-in. cylinders. There were two drums, each having a diameter of 18 in. and face width of 38 in. to hold 1,000 ft. of $\frac{3}{8}$-in. wire rope in four layers; and also two drums, each 24 in. in diameter and having a face width of 16 in., to hold 400 ft. of $\frac{3}{4}$-in. wire rope in three layers.

The discharge pipe was supported on 16 intermediate and one terminal pontoon. It was also found necessary at times to use two

pontoons, each 6 ft. wide, one on each side of the dredge, to secure necessary stability while in operation. See Fig. 110.

The excavation began October 1, 1906 and was worked one eight-hour shift daily, during the early part of this month. Later, two eight-hour shifts were used and from November, 1906 on, three eight-hour shifts were used. The work of the dredge was in charge of a chief engineer and a chief operator. Following is the labor schedule for each eight-hour shift.



Discharge Pipe of Hydraulic Dredge.
Figure 110.

1 operator,	@	$100.00 per month
1 engineer,	@	100.00 per month
1 engineer,	@	80.00 per month
3 firemen,	@	70.00 per month each
1 spudman,	@	60.00 per month
1 oiler,	@	50.00 per month
4 deckhands,	@	50.00 per month each.

Besides the above force was a gang which moved the discharge pipe and repaired the levees along the canal and behind which the spoil was deposited. An engineer or operator for the gasoline launch, which towed the fuel scow, and a night watchman, were also constantly employed.

The following table gives the labor costs of excavation for this hydraulic dredge during the month of November, 1906:

TABLE XXIV.

COST OF LABOR FOR HYDRAULIC DREDGE

Description	No. of days	Rate	Amount
1 chief engineer	30	$150.00	$150.00
1 chief operator	30	135.00	135.00
3 engineers	86	100.00	286.67
3 engineers	86	80.00	229.33
3 operators	86	100.00	286.67
9 firemen	258	70.00	602.00
3 spudmen	86	60.00	172.00
3 oilers	86	50.00	143.33
12 deckhands	344	50.00	573.33
1 night watchman	30	1.60	48.00
1 foreman	$34\frac{1}{4}$	3.00	102.75
1 foreman	$37\frac{3}{4}$	2.00	75.50
Laborers	$1{,}056\frac{1}{2}$	1.60	1,690.40
1 engineer, tug	30	80.00	80.00
			$4,574.98

Amount of excavated material, 144, 882 cu. yd.
Cost of excavation, $4,574.98 ÷ 144,822 = $0.0316 per cubic yard.

The "laborers" were those in the gang employed in moving the discharge pipe and repairing the levees.

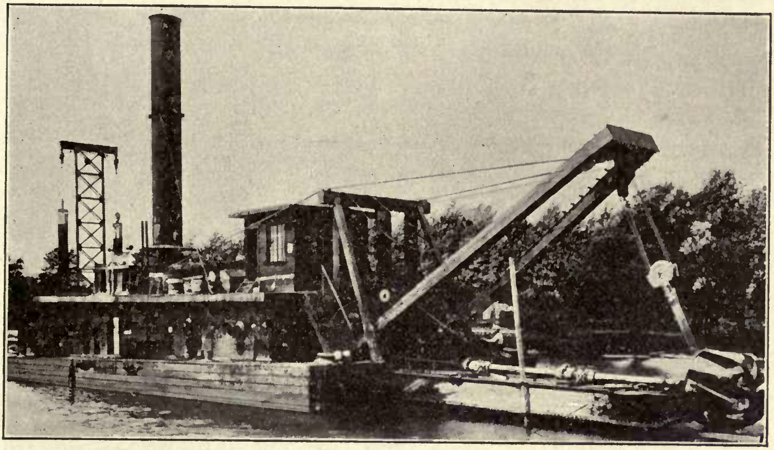
91b. Use in Chicago.[1]—During the seasons of 1907 and 1908, an extension to Lincoln Park of Chicago, Illinois, was made by filling in a large area with material excavated from the bed of Lake Michigan. A specially designed hydraulic or suction dredge was used. The material excavated was a stiff blue clay, mixed with gravel and stones. Part of the work was in water to a depth of 18 ft. and the dredge was designed exceptionally strong and seaworthy, so as to withstand the sudden and severe storms of the Lake. Fig. 112 gives a view of the dredge in operation.

The hull was made of steel and had an overall length of 148 ft., a beam width of 38 ft., and a depth of $10\frac{1}{2}$ ft. A superstructure or deck house extended over nearly the whole length of the hull and a pilot house was located near the front end and just above the deck house.

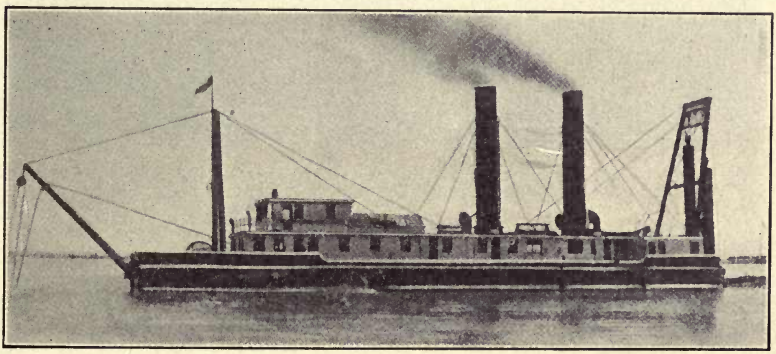
An A-frame boom was hinged to the bow of the hull and was stayed back to a vertical fixed A-frame, placed a short distance

[1] Quoted from Engineering News, February 27, 1908.

back on the hull, from the bow. From the point of the A-frame boom by means of sheaves and wire rope, was suspended the steel ladder frame, which carried the suction pipe. The ladder was 40 ft.



View of Hydraulic Dredge showing Cutter, Cutter Frame and Gantry and Spuds and Spud Gantry.
Figure 111.



Hydraulic Dredge Operating in Lincoln Park, Chicago.
Figure 112.

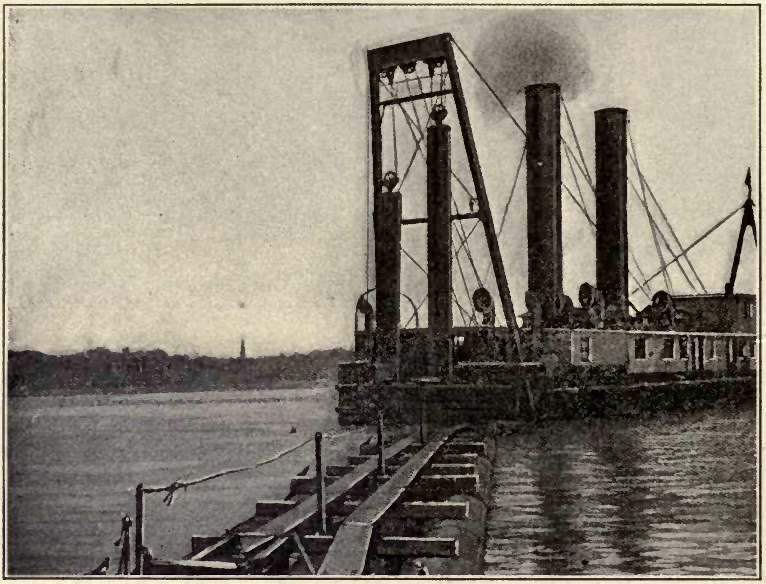
long, and by means of the suction pipe, excavation could be made to a depth of 32 ft.

A large gallows frame, at the stern of the hull, was used to suspend the two spuds.

The centrifugal pump was operated by a triple-expansion engine

of 1,200 h.p. Steam was supplied by two Scotch Marine boilers, $11\frac{1}{2} \times 18$ ft., each boiler being provided with four furnaces.

The suction pipe had a diameter of 30 in. and at its outer end a cutter was operated, which was a steel casting 9 ft. in diameter and weighing 9 tons. It was made up of eight blades, which curved outward and backward from the shaft and were bolted at their outer ends to a circular steel plate. The blades were equipped with



Rear View of Hydraulic Dredge Operating in Lincoln Park, Chicago.
Figure 113.

renewable cutting edges of hard steel. The cutter was operated by an independent, tandem compound engine of 300 h.p.

The discharge pipe was composed of riveted steel pipe having a diameter of 30 in. and in lengths of 93 ft. 6 in. The adjacent sections were connected by specially made ball-and-socket joints, provided with steel springs to relieve the joints from lateral and longitudinal stresses. Each length of pipe was supported between two 33-in. cylindrical steel pontoons about 100 ft. long. The pipe line and pontoons are shown in Fig. 113.

During the season of 1907, the dredge worked $122\frac{1}{2}$ days of 24 hours each, and the total excavation was 457,242 cu. yd. The

maximum excavation per hour was 866 cu. yd. and the average was 426 cu. yd. per hour. The material pumped averaged 10 per cent. of solid matter.

92. Electric Power for Operation.—In very recent years, the remarkable development of cheap electric power, and especially that of water-power, has led to the use of electric power in the operation of dredges. As the water-power of our rivers becomes developed and as the power facilities of the cities of the South and West are increased in size and number, it will be found to be more economical to run an electric transmission line to the scene of a dredging project, rather than to haul coal or oil over long distances and bad roads from the nearest railroad station.

92a. Use in Washington.—As a recent example of the use of electric power in the operation of a hydraulic dredge, the following description of the dredge "Washington" will be given.

This dredge was built by the Tacoma Dredging Company of Tacoma, Washington, for the dredging out of the Puyallup River in Tacoma harbor.[1]

The dredge was operated by electric power taken from one of the 60,000-volt, 60-cycle, three-phase transmission lines of the Seattle Tacoma Power Company. This voltage was stepped down to 2,300 volts at a temporary substation, located near the scene of the work. From the substation the distributing circuit was carried on a temporary pole line along the water's edge. The switchboard panel in the pilot house of the dredge was connected to the distributing circuit by a three-phase flexible cable, of sufficient capacity to transmit electric power equivalent to a total of 1,500 h.p. This cable was carried along the discharge pipe, from which it extended to the shore line at convenient points.

The electrical equipment of the dredge provided for the operation of the cutter, the spuds, the pump and the several auxiliaries.

The cutter was operated by a wound rotor type, 150-h.p., 2,300-volt, 690-r.p.m., semi-enclosed motor. A drum type reversing controller, with gird resistance, was used to operate the motor from the pilot house. The motor was equipped with a special bearing and was connected to the cutter by double reduction gearing. The whole equipment was designed to operate at the angle at which the cutter was operating, the normal position of operation being at an angle of about 45 degrees with the horizontal.

[1] Quoted from the Electric Journal, March, 1910.

The cutter was raised and lowered by a direct-connected hoist, which was driven by a 30-h.p., 220-volt, two-phase, 850-r.p.m., wound rotor type motor. This motor was also controlled from the pilot house by a drum type reversing controller with gird resistance.

Two large timber, iron-shod spuds were located in the stern of the dredge. They served to brace the dredge as the cutter moved forward into the bed of the stream. By raising and lowering these spuds alternately, the dredge could be swung in an arc and allow the cutting of a channel 40 to 50 ft. wide and from 10 to 15 ft. deep. The spuds were operated by a 60-h.p., 220-volt, wound rotor type motor.

The main suction pump was of the single-runner centrifugal type, operating at a speed of 460 r.p.m. It was located about amidships and connected by a rope drive to two 500-h.p., 2,300-volt, self-contained wound rotor type motors. The two motors were operated in multiple on a single shaft.

The discharge pipe was a 26-in. diameter, wooden-stave pipe and took care of a discharge of 21,000 gal. per minute.

Several smaller motors of the squirrel-cage type were used for the operation of small auxiliaries, such as a lathe, an air pump, etc.

This dredge was in operation a little over a year and worked very satisfactorily. The power equipment furnished a continuous load of from 900 to 1,250 h.p. for 24 hours a day and seven days a week. The dredge handled 30,000,000 gal. of a heavy solution of mud and water per 24-hour day.

93. Résumé.—The hydraulic dredge has been in use during the past 50 years. For many years its use was restricted to the removal of soft material such as sand, loose gravel, silt, mud, etc. It is doubtless the most efficient type of excavator for this purpose and has been used generally in this country on harbor work, on the Mississippi River, and for the filling in of large areas of waste lands.

Recently, the hydraulic dredge has been adapted to the excavation of hard materials, such as clay, hard gravel, and stiff mud, by the use of a cutter. In the earlier designs the cutter head was simply an agitator to stir up and mix the loose material with water, so that it could be easily drawn into and up through the suction pipe. The present dredges use the cutter as an excavator to cut and loosen the harder material and force it into the suction pipe.

This type of dredge has the peculiar advantage of being able to dispose of the excavated material at any side of the machine and at a considerable distance. This is of especial value in the filling in of low waste lands along rivers, harbors and lakes.

The hydraulic dredge is not an economical type of excavator to use in canal work and in the construction of levees. The material as it emerges from the discharge pipe contains so large a proportion of water that it will not remain in place unless retained behind artificial bulkheads or banks.

The capacity of and cost of excavation with a hydraulic dredge depend on local conditions. The dredge is generally built under special requirements and there are no general rules which can be applied to all cases.

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CHAPTER VIII

TRENCH EXCAVATORS

95. Classification.—The rapid development of sanitary and drainage engineering during the past quarter of a century has led to the general construction of sewer, water-supply and drainage systems. The large amount of trench excavation made necessary for the installation of these improvements has led to the design of special excavators. In work of any magnitude, these machines are much more efficient and economical than hand labor.

Trench excavators may be divided into two general divisions, viz:

(1) Sewer and water-pipe trench excavators.

(2) Drainage tile trench excavators.

SECTION I. SEWER AND WATER-PIPE TRENCH EXCAVATORS

96. Classification.—This class of excavators will be considered in five different groups or types, as follows: (a) The traveling derrick or locomotive crane; (b) the continuous bucket excavator; (c) the trestle cable excavator; (d) the tower cableway; (e) the trestle track excavator.

A. THE TRAVELING DERRICK

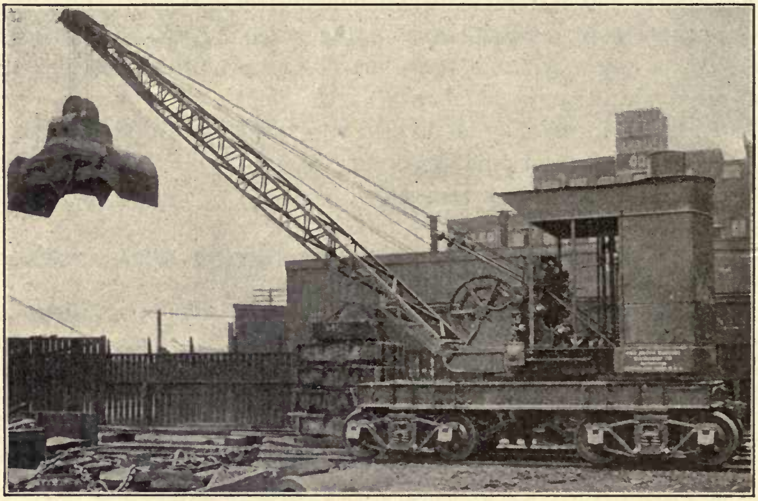
97. General Description.—The traveling derrick or locomotive crane is similar in construction and operation to the revolving shovel described in Chapter V. The machine consists essentially of a derrick and a double-drum hoisting engine mounted on a platform car.

The smaller sizes of cranes are mounted on four-wheel trucks, equipped with either broad-tired wheels for ordinary road traction or with standard railroad wheels. The larger sizes of cranes, generally above 10-ton capacity, are mounted on two four-wheel trucks of the Standard M. C. B. railroad type. These trucks support a steel-frame platform equipped with drawbars for the four-wheel type and with M. C. B. couplers, steam brake, train pipe, grab handles, steps, etc.

The upper or swinging platform is pivoted to the lower or stationary

one and by means of a gearing can be made to revolve in a circle. This platform is a steel frame, to the front end of which is hinged the boom. Behind the boom is placed the two engines and at the rear end the boiler or motor is set, if electric power is used. The machinery is generally housed to furnish a protection against the weather.

It consists of two reversible link-motion vertical engines, which operate a moving gear for the propulsion of the machine, a reversible swinging gear to swing the upper platform and bucket and the drums for the handling of the bucket.



Travelling Crane Equipped with Grab Bucket.
Figure 115.

The power used is either steam or electric. In the case of the former, a vertical type of steam boiler is used, and the steam is fed direct to the cylinders of the engine. Electric power is commonly used for street railway work and is cleaner, cheaper and smoother in operation than steam power. The equipment for an electrically operated crane would be similar to that for a revolving steam shovel. See Art. 28, Chapter V.

The crane or boom is generally a latticed steel framework, widened out to the width of the platform at its lower end and narrowing to a sufficient width at the upper end to carry the sheaves. The boom may be raised and lowered by cables attached to its outer end from a winch on the engine.

Wire cables lead from the engine drums out over the sheaves at the end of the boom and then down to the bucket or skip. A grab bucket of the clam-shell or orange-peel type may be used or a simple skip or bucket for the hoisting of excavated material. Fig. 115 shows a 20-ton crane with a grab bucket. This machine is being used on the Panama Canal.

A scraper bucket may be used for the excavation of trenches or ditches. See account of such a machine given in Art. 47, Chapter VI. A drag line and separate drum must be used in this case.

For descriptions of the various types of buckets see Art. 26, Chapter V, and Art. 44, Chapter VI.

The following set of blank specifications of the Brown Hoisting Machinery Company of Cleveland, Ohio, give a general idea of the make-up of a standard type of locomotive crane with grab bucket.

SPECIFICATIONS FOR FOUR-WHEEL, —TON LOCOMOTIVE CRANE, SUPPLIED WITH GRAB-BUCKET EQUIPMENT

See Clearance Sketch No.............and Photo No...............herewith
For...

....

Gage of track.............ft................in.

CAPACITY.—The crane on above gage of track has power, strength and stability to safely handle the following loads at the given radii, without the use of rail clamps or outriggers, and will swing these loads through a full circle, and will move the same along tracks with boom in any position:

At radius......lb.
At 15 ft. radius......lb.
At 20 ft. radius......lb.
At 25 ft. radius......lb.
At 30 ft. radius......lb.
At 35 ft. radius......lb.
At 40 ft. radius......lb.
At 45 ft. radius......lb.
At 50 ft. radius......lb.

Note.—These lifting capacities are based on tracks being in good condition and with 16,000 lb. counterweight in truck. By using track clamps (provided with crane) these lifting capacities are increased. If tracks are in bad condition, these capacities will be diminished.

FUNCTIONS AND SPEEDS.—The crane, under its own steam, to have the functions of hoisting, rotating, track travel, and boom lowering. The hoisting, traveling and rotating may be utilized simultaneously with full load or any function may be used independently, as desired, and at approximately the following speeds:

Hoisting, grab bucket; full load, 140 ft. per minute.
Hoisting, grab bucket; empty, 180 ft. per minute.

Hoisting, full load with block on four-part line, 70 ft. per minute.
Hoisting, empty hook on four-part line, 110 ft. per minute.
Rotating, full load, when at specified radius, 4 complete turns per minute.
Rotating, empty hook, 6 complete turns per minute.
Track travel, full load on straight level track, 500 ft. per minute.
Track travel, empty hook on straight level track, 600 ft. per minute.
Possible grade, with full load. . . .per cent.
Possible grade, with empty hook . . . .per cent.
Minimum radius curve, 70 ft.
Maximum draw-bar pull on straight level track . . . . . .lb.

General Description.—The crane in general consists of a structural steel truck frame which sets on trucks, a heavy cast-iron truck bed, which is riveted and bolted into truck frame; a rotating bed and housings upon which engine and crab mechanism are mounted; a large heavy cast-iron combined counterweight and water tank, also used for boiler support; a boiler, engines, crab mechanism and boom.

Truck Frame and Trucks.—This frame is made of I-beams, plates and channels, and constructed to fit cast-iron truck bed and also form a convenient receptacle for counterweight. The entire crane is mounted on four wheels, 28 in. in diameter, having standard M. C. B. chilled treads, with axles forged from a special steel. Axles are 5-in. diameter in the journal, 6-in. in the wheel-seat, and with journals running in bronze half-boxes with large receptacles for oil.

Counterweight.—In the truck frame, space is provided for 16,000 lb. of counterweight. This counterweight would consist of pig iron, punchings, scrap, etc.

Note.—This counterweight is always furnished by customer.

Engines.—These consist of a pair of vertical cylinders, 9-in. diameter, 7-in. stroke, coupled at right angles, and mounted on the housings. Engines have link-motion reversing gear, wide-ported slide valves, and are equipped with suitable lubricators, dripcocks, etc. Speed 350 r.p.m. under full load. The connecting rods, eccentric rods, valve stems and suspension pins are made of manganese bronze. Cylinders, guides and stuffing boxes are bored at same setting, thus insuring perfect alignment. Pistons can be removed without disturbing cylinder.

Note.—Vertical engines on locomotive cranes are preferable to horizontal, as they cause less vibration to the machine. This is noticeable when used on a bridge, trestle or other structure, which might be injuriously affected by any excessive vibratory action.

Boiler.—The boiler is of the vertical tubular type, possessing quick steaming qualities and large steam capacity. It is 54 in. in diameter and 8 ft. 3½ in. high. There are 110 tubes of seamless steel, each 2½ in. in diameter, with copper ferrules. The boiler has double-riveted vertical and single-riveted circular seams. The shell is of ⅜-in. fire-box steel, and the heads of ⅝-in. fire-box steel. The boiler has a large fire-box, is of ample capacity to supply steam for all conditions of work, and is fitted with best make of water-gage, steam-gage pop-safety valve, blow-off valve, etc., and injector for boiler feed. The entire boiler is heavily

lagged with magnesia, with outside surface of sheet steel; working steam pressure, 100 lb.

Hoisting Mechanism.—Consists of a main or hoist drum, and a holding or shell-rope drum. The hoist drum is driven from a friction clutch on the main engine shaft through a train of cast-steel gearing with machine-cut teeth. The shell drum is driven from the hoist drum by a suitable slip friction. The amount of friction is controlled by an adjusting device on the end of the drum shaft, designed to maintain a slight tension on shell rope during the operation of closing and hoisting bucket. Both drums are of sufficient size to receive their respective ropes in a single layer; all overwinding and consequent wear of ropes is thus avoided. Each drum is provided with a brake of ample size, and all levers are within easy reach of operator, who has at all times perfect control of crane and bucket. Wood friction blocks between hoist and shell drum can be replaced in a few minutes' time without taking out drums.

Rotating Mechanism.—(Grafton's patent. The Brown Hoisting Machinery Co., sole licensees.) Consists of two friction clutches driving a train of gears, the last two of which are on a nickel-steel shaft; the pinion on the lower end of this shaft meshes into a slip-ring of large diameter, whereby rotating in either direction may be accomplished without reversing the engines. This slip-ring is made of non-welded forged steel like a locomotive tire, and has teeth cut in its periphery; said ring resting loosely on a properly turned bearing or seat on the upper surface of the truck bed. The upper surface of the slip-ring, which is beveled, forms the bearing or path for the conical rollers carrying superstructure. There are six of these rollers, four in front to take the thrust of the boom, carried in pairs by steel equalizers, and two in rear. The slip-ring is free to move in either direction, when the rotating clutch is thrown into gear, but is retarded in this motion by the frictional resistance between the ring and its seat, due to the weight of the crane superstructure and load resting on it. The action of the slip-ring is therefore that of a safety cushion when rotating the crane under light or heavy loads, and the resistance of the ring to rotating is directly proportional to the load hanging on the crane. These several parts are so nicely adjusted that by this simple means all tendency to shock is avoided, and rotation may be effected in either direction, or may be reversed as frequently and as quickly as desired, without any danger of breaking or even straining any part of the mechanism.

Note.—The gain in time and convenience to the operator by using this slip-ring is very apparent when the crane is seen in service. A crane thus constructed is far safer, more convenient, and more rapid in action than one not provided with such a frictional safety device, and our cranes, therefore, have an actual capacity of from 20 to 40 per cent. greater than any other crane, to say nothing of the reduced cost of repairs.

Traveling Mechanism. This mechanism is driven by a friction clutch on a shaft geared to the crank shaft and consists of a train of gears, one of the shafts of which passes down through the hollow center pin. This pin is the axis of rotation of upper part of crane. On the lower end of this shaft is a bevel pinion meshing with a bevel gear on a longitudinal shaft on the ends of which are bevel pinions that mesh with gears of truck-wheel axles. The truck-wheel axle gears are split and easily removable when making repairs.

Boom.—Boom is built up of four heavy angles, securely latticed together in both horizontal and vertical planes. The two angles forming either side of boom

are brought as near together at the ends as proper connection will permit and between these points the angles are bent to a parabolic curve. The greatest vertical depth of boom is therefore at the middle point of its length, and the parabolic curve of angles, relieving the lacing of all compressive stress, renders this the strongest shape possible.

The angles forming the horizontal bracing are laced together in a vertical plane at alternate panels, forming diaphragms which rigidly maintain the rectangular cross-section of boom.

The least horizontal width of boom is at the upper or head end and the greatest at the foot or lower end, where connection is made to rotating bed of crane, giving ample lateral stability when rotating the heaviest loads at maximum speeds.

The boom may be lowered until head end is level with track without injury, thus rendering it practically impossible for the boom feet to be broken off by carelessness of operator.

The head of boom is provided with a suitable pin carrying the sheaves for both hoisting and radius-varying ropes. The hoist rope sheaves are arranged to shift readily on pin so that when using a "Brown-hoist" bucket, it may be hung in such a way as to open either parallel or at right angles to the boom. This is an exceedingly valuable feature.

All sheaves are provided with ample rope guards, which positively prevent the rope becoming fouled.

The change from bottom block to bucket may be made in a very short time.

Radius-changing Gear.—This consists of a drum driven by worm gearing, from the main shaft, by means of a positive clutch, which is held securely in place by a quadrant. The worm wheel is of bronze and worm of steel, both having cut teeth. The boom is supported from the drum by six parts of $\frac{3}{4}$-in. plow-steel wire rope running through equalizing sheaves. A clamp operates on the worm shaft to hold mechanism when clutch is thrown off. By running the engines in the proper direction, the radius may be varied from ...... ft. maximum to ...... ft. minimum when equipped with grab bucket; and ...... ft. maximum to ...... ft. ......in. when equipped with bottom block.

Gears.—All gears are of steel and all spur gears have teeth cut from the solid.

Clutches.—All clutches except radius-varying are of the disc friction type, built for rapid operation and designed and located for quick and easy adjustment. The adjustment of the clutch is only the matter of loosening one binding screw and turning adjusting nut to right or left as desired. This one-point adjustment insures uniform pressure over the whole face of the friction blocks.

Operating Levers.—The functions of hoisting, rotating and traveling are controlled by levers, one above the other, that move in a horizontal plane about a common vertical axis. These levers are conveniently located to be manipulated by the operator with the left hand. The shell brake lever is conveniently located to be handled with the right hand. The hoist brake is controlled by a foot lever. Reversing lever is about central on the operator's platform and is convenient for the operator to handle with the right hand. The clutch for boom hoist is controlled by a hand lever near the right-hand side of operator's platform. The throttle is controlled by hand levers, dropped down from the roof of the cab in front of the operator. There are three of these levers, one convenient for the operator when in position to work the other levers, and one at

each side of crane, so that when traveling backward, the operator can stand on either side, inside the cab, and look out the door in direction of travel and see that the track is clear. The operator's platform is raised up so that he can look over the drums and have a good view of his lift at all times.

HALF CAB.—A half cab, with roof over operator is furnished, consisting of light angle-irons covered with sheet steel.

Note.—A full cab, having, in addition to above, sheet steel sides and ends, with two sliding doors with windows, can be furnished when required, at additional cost.

DRAW BAR.—A draw bar is supplied for coupling crane to railway cars, so that crane can be used to switch cars. Both ends of truck frame are equipped with necessary brackets to enable draw bar to be used at either end.

WATER TANK.—There is provided a cast-iron water tank with a capacity of ...... gal.

BOTTOM BLOCK.—A bottom block is provided for use with crane when used for handling miscellaneous material. Block to have two sheaves and to hoist the load on four parts of rope. Sheaves to be of ample size for the diameter of rope used, to have machine turned score, and bronze bushing. Side plates of block to be made from soft steel plate. Hook to turn in a swivel cross-head.

COAL SUPPLY.—The crane coal bunker has a capacity of 1,000 lb.

ROPES.—All ropes are best grade of plow steel.

TRACK CLAMPS.—Four pairs of track clamps are furnished and suitably attached to the crane for clamping same to the rails at four points, to give additional stability, or to hold crane on grades when necessary.

TOOLS.—There is provided with every crane, a complete set of firing tools, a flue cleaner, oil cans, wrenches, etc.

CLEARANCES.—Extreme height of crane, 16 ft. 2 in.
Extreme width of crane, 10 ft. 0 in.
Wheel base, 8 ft. 0 in.
Rear overhang of rotating parts, 9 ft. $10\frac{1}{2}$ in.

Note.—Where absolutely necessary, the height of crane can be reduced to 14 ft. 0 in. by removing the stack, which is bolted.

GRAB BUCKET.—The equipment includes a Brown patent two-rope grab bucket of ...... cu. ft. capacity, suitable for handling ....

MATERIAL.—The material entering into the construction is the very best obtainable. Exhaustive tests, together with years of experience in building locomotive cranes, has enabled us to determine exactly the kind and grade of material best suited for each detail.

WORKMANSHIP.—The workmanship on these cranes throughout is of the highest order. Holes are bored to micrometer sizes and details made to gages, thus insuring positive duplication of parts when needed for repairs. Shafts are of best grade of forged steel enlarged in diameter where press or drive fits are used. This practice insures parts intended to be a tight fit, remaining so, as well as facilitates making repairs by avoiding the necessity of driving the part to be removed, more than the length of the fit; and from that point it can be removed with the hands. All parts of these cranes are subjected to a rigid inspection in detail, during the process of machining, as well as a general inspection after assembling and during tests, which are given all cranes before shipment.

Weight.—Total weight of crane and bucket, without counterweight, coal or water, is approximately ...... lb. With counterweight ...... lb.

Lettering.—Cab will be lettered and numbered to suit purchaser.

All-rail Shipment.—For all-rail shipment, the crane is shipped assembled as far as possible, in a drop-end gondola car; the only detached parts being the boiler, boiler fittings, boom and ropes, these together with the bucket being loaded in a separate gondola car accompanying the crane. The injector, valves, etc., are boxed and strapped to the car floor.

Ocean Shipment.—For ocean shipment, the crane would be "knocked down" and boxed. All parts to be properly marked to facilitate assembling. All packages marked with customer's mark, contents, gross and net weights and dimensions, and numbered from one up.

Slings are made on all heavy packages to avoid breakage and assist in handling.

Shipping and detail packing lists to be furnished at time of shipment. An extra charge is made for this boxing for export.

Catalogue of Parts, etc.—With each crane a book of photographs, showing all crane parts, properly numbered, is supplied. Printed instructions, covering the erecting of the crane, its care and operation are furnished.

THE BROWN HOISTING MACHINERY CO.

By ....

.... 191..

97a. Use in Indiana.[1]—A simple form of locomotive crane was used during the season of 1908 for the excavation of a sewer trench in Gary, Indiana. The excavator consisted of a $\frac{3}{4}$-cu. yd. Hayward orange-peel bucket operated by a 25-h.p. hoisting engine and a separate swinging engine. The whole machine was mounted on a heavy platform supported on rollers and moved ahead by means of a wire cable attached to a "dead man" ahead.

The trench had a rectangular cross-section of 30 ft. width and a depth of 12 ft., and in the bottom was a secondary rectangular channel, 10 ft. wide and 4 ft. deep. The material excavated was a fine lake sand and the last 3 to 4 ft. of excavation was in water.

The labor schedule was as follows:

1 Engineer @ $6 per day
1 foreman @ $3.50 per day
5 laborers @ $1.50 per day

The work was commenced on April 2, 1908, and the first 1,830 ft. were completed May 31, 1908. The machine was shut down five days for repairs and a night crew worked 13 extra shifts, so that a total of 51 shifts or working days were used for this work.

The following table will give the cost of the work:

[1] Abstracted from Engineering-Contracting, July 15, 1908.

Labor:

1 engineer @ $6,	$306.00	
1 foreman @ $3.50,	178.50	
5 laborers @ $1.50,	382.50	
Extra labor of engineer and fireman for 5 days making repairs,	47.50	
Total labor expense,		$914.50

Fuel and Supplies:

Coal,	$255.00	
Oil, waste and repairs,	65.00	
Total,		$320.00
Grand total expense,		$1,234.50

Total amount of excavation, 21,250 cu. yd.

Cost of excavation; $\$1234.50 \div 21{,}250 = \$0.058$ per cubic yard.

97b. Use in Kentucky.—[1]Three Browning locomotive cranes were used during the season of 1910 in the excavation of a large sewer trench in Lousville, Kentucky.

The trench was 2,723 ft. long, the average depth of excavation was 22.4 ft., and the average amount of excavation per linear foot of trench was 12.25 cu. yd. The material excavated consisted of blue and yellow clay to a depth of 6 ft., yellow clay and loam for the next 6 to 12 ft. and this was underlaid with fine and coarse sand.

The excavators were 10-ton Browning locomotive cranes, one of which was equipped with an automatic orange-peel bucket of 1 cu. yd. capacity and one with an automatic clam-shell bucket of ½ cu. yd. capacity. The cranes ran on a standard gage track of 60- and 65-lb. rails. The cranes operated as follows: Crane No. 1, equipped with an Owens clam-shell bucket, moved along the trench and excavated the first 10 to 12 ft. The sheeting was started as soon as practicable and Crane No. 2, equipped with a ¾ cu. yd. bucket, followed and removed the balance of the cut to grade. The excavated material with the exception of the sand was dumped into a spoil bank along the opposite side of the trench from the track. The sand was dumped into a screen and used for concrete. Crane No. 3, brought up the rear and did all the back-filling and pulling of sheathing and timbering.

The following are the labor costs per working day of 10 hours:

[1] Abstracted from Engineering-Contracting, June 29, 1910.

CRANE NO. 1

1 engineer,	$3.50
1 fireman,	2.00
1 tagman,	1.75
1 signalman,	1.75
Total labor cost,	$9.00
Average excavation,	200 cu. yd.
Cost of excavation for labor,	$0.045 per cubic yard.

CRANE NO. 2

1 engineer,	$3.50
1 fireman,	2.00
1 foreman,	2.00
8 laborers, @ $1.75,	14.00
Total labor cost,	$21.50
Average excavation,	225 cu. yd.
Cost of excavation for labor,	$0.095 per cubic yard.

CRANE NO. 3

1 engineer,	$3.50
1 fireman,	2.00
1 signalman,	1.75
Total labor cost,	$7.25
Average excavation,	500 cu. yd.
Cost of excavation for labor,	$0.0145 per cubic yard.

The average amount of coal used per crane per day was 1,200 lb. at a cost of $4 a ton. About 160 gal. of water were used per crane a day.

The cranes cost $5,000 each and annual interest and depreciation was allowed for at the rate of 15 per cent.

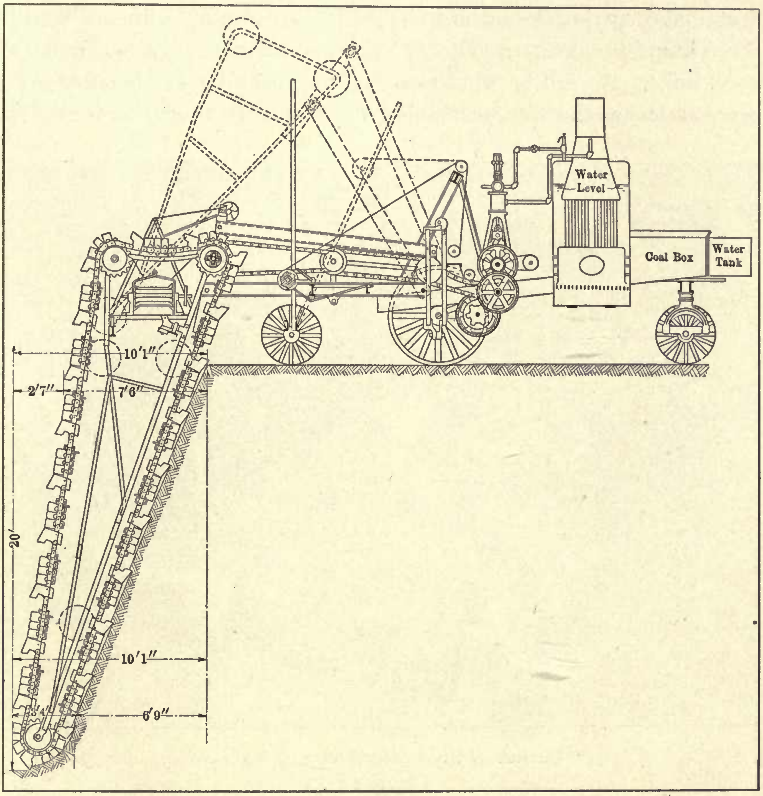
B. THE CONTINUOUS BUCKET EXCAVATOR

There are several makes of machines built on the principle of the continuous excavator or ladder dredge, which are used for the excavation of trenches with vertical sides, widths of from 12 to 78 in. and depths up to 20 ft. Three of the best known will be described.

98. Parsons Traction Trench Excavator.—This excavator is built by the G. W. Parsons Co. of Newton, Iowa, and is commonly used on trench work for sewer and water pipes throughout the central West.

The machine consists of two frames, the rear and main frame is sup-

ported on four steel broad-tired wheels and carries the engines, the boiler, coal box and water tank, the front frame is supported on two steel wheels and its rear end is attached to the main frame while the front end carries the digging ladder. The two frames are hinged together so that in moving over hilly or uneven ground the ladder may



Parsons Trench Excavator.
Figure 116.

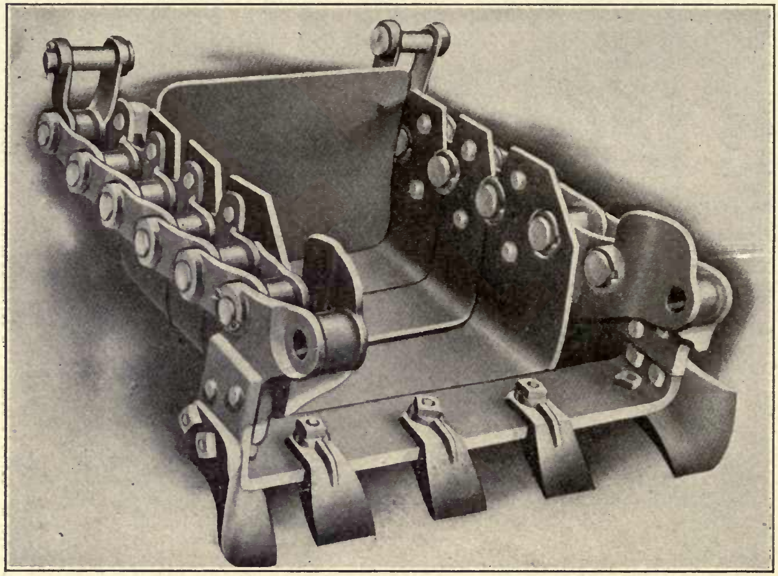
be kept to grade and in a fixed position. The entire machine is built of steel and weighs from 22 to 24 tons, depending on the width of the buckets. Fig. 116 shows the construction of the excavator.

The coal box and water-tank are made of steel plates and are carried on the rear of the main frame over the rear wheels. They are of sufficient capacity to carry fuel and water for one-half day's work.

The boiler is placed on the central portion of the main frame and is

a vertical tubular boiler of standard make. The engines are set in front of the boiler and nearly over the central wheels of the machine. These are of the single cylinder vertical type and supply power through gears and sprocket chains to the bucket chain, the disposal conveyor and the central axle for traction.

A triangular steel framework is supported from the front of the front frame and carries the bucket chain on three sets of sprocket wheels. The chain is made up of 22 to 24 buckets connected together by heavy steel links. As will be seen from Fig. 117, each bucket is made up of four sections, the first section having five teeth bolted to it and the



Bucket of the Parsons Trench Excavator.
Figure 117.

other sections forming the body of the bucket to contain the excavated material. The sections are each connected to the links by steel pins which give flexibility and readily conform to the excavation of material of varying density and easily dump the material, always leaving the bucket clean.

The excavating ladder swings automatically from one side to the other of the rear frame and thus with the smaller size of machine trenches with widths from 29 to 60 in. may be dug. With the larger machine a width of trench up to 78 in. can be excavated. This has

the advantage of varying the width of cut without changing the buckets and also the making of a manhole at any point without delay.

When obstructions are met during the excavation of a trench, such as boulders, roots, etc., the excavating wheel may be raised over them and fed down into the earth on the other side. While in operation the excavator occupies a space of 8 ft. at the top and 3 ft. at the bottom of the trench. The rear of the chain is in nearly a vertical position and pipe can be laid to within 3 ft. of the face of the trench. This face or head has a slope of 4 ft. in a depth of 20 ft.

98a. Cost of Operation.—The manufacturers, as a result of several years' use of their machines, have compiled the following table of comparison between machine and hand labor in trench excavation:

HAND WORK

Foreman,	Per day,	$4.00	
Timberman,	Per day,	3.00	
Helper,	Per day,	2.50	
Pipe layer,	Per day,	3.00	
Helper,	Per day,	2.50	
40 laborers @ $2.00	Per day,	80.00	
Total,			$95.00

MACHINE WORK

Engineer,	Per day,	$4.00	
Fireman,	Per day,	2.50	
Coal,	Per day	5.00	
Oil and waste,	Per day,	1.00	
Water,	Per day,	1.00	
Team,	Per day,	4.00	
Foreman,	Per day,	4.00	
Pipe layer,	Per day,	3.00	
Helper,	Per day,	2.50	
Timberman,	Per day,	3.00	
Helper,	Per day,	2.50	
2 teams back-filling, @ $4	Per day,	8.00	
2 Helpers, @ $2	Per day,	4.00	
Total,			$44.50
Interest, depreciation and repairs,			$10.00
Total for machine work,			$54.50
Total for hand work,			$95.00
Saving per day,			$40.50

On the assumption that by hand labor each man excavates 7 cu.

yd. per day, a total excavation of 315 cu. yd. per day will be made. On a trench 28 in. wide and 12 ft. deep, this crew will dig 315 lin. ft. of trench per day. At 7 cents per cubic yard for back-filling, the latter will cost $22 for the return of the 315 cu. yd. to the trench. This will make a total cost of $117 for a day's work.

Assuming that the machine excavates 250 lin. ft. of the same size trench in a day's work of 10 hours duration, the cost of operation, fuel, oil, waste, water, interest on investment, repairs and depreciation will be $25. The cost of laying pipe, timbering trench, back-filling trench, etc., will amount to $29.50 per day, making the total cost $54.50.

The above statement indicates that during a 10-hour day an excavator will do about 80 per cent. of the amount of trench excavation which can be done by hand labor at about 60 per cent. of the cost.

99. Chicago Trench Excavator.—This excavator is made by the F. C. Austin Drainage Excavator Company of Chicago, Illinois. The following table gives the general data of the trench excavators made by this Company. Sizes Nos. 000, 00, Special 00 and 0 are generally used in drainage tile work and will be described in Division II of this chapter.

This excavator consists of a steel frame carrying the machinery and at the rear end the excavating chain and its framework. The platform is made up of steel I-beams strongly framed together and supported on four broad-tired wheels. For soft soil excavation the two rear wheels are generally replaced by rolling platform tractors.

The boiler is mounted on the front part of the platform and generally of the horizontal, locomotive type. On the top of the boiler is placed a single-cylinder, reversible engine. See Fig. 118.

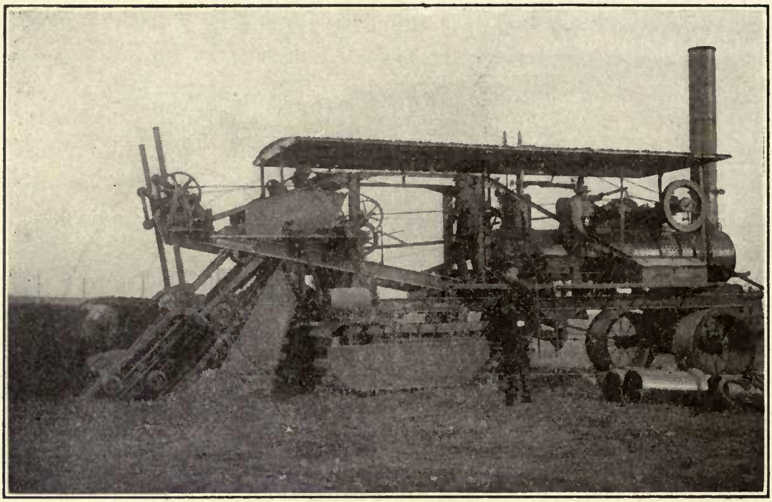
The main shaft of the engine is belt-connected to a shaft on the rear of the frame. On this latter shaft is a sprocket wheel connected with a link-belt driving-chain to the shaft at the head of the cutter frame. Similar vertical chains drive the bevel gears which operate the belt conveyor.

A sloping frame extends over the rear of main platform, made up of two channels braced at intervals with cross-pieces. This frame supports the upper end of the excavating chain which is pivoted to a shaft above the rear end of the main platform. The excavating chain is carried by a steel frame with a length of about 20 ft. pivoted (as noted before) at its upper end and free at its lower end. The shafts at the ends of this frame are provided with hexagonal sprocket wheels over which move a pair of endless link-belt chains. These

TABLE XXV

GENERAL DATA OF DITCHING MACHINE

Size No.	Horse-power		Maximum depth	Width of cuts[1]	Max. digging speed per min.	Traction speed per hour	Delivering dirt on either side	Width of machine on car	Height of machine over all	Approximate gross weight
	Steam	Gasoline								
000	....	18	6′ 0″	12″, 15″, 18″	10′	1½ miles	One side	8′ 0″	10′ 0″	18,000
00	18	24	8′ 0″	15″, 18″, 24″	9′	1½ miles	Either side	9′ 0″	11′ 0″	22,600
Spec. 00	....	36	9′ 6″	15″, 18″, 24″	9′	1½ miles	Either side	9′ 0″	11′ 0″	24,000
0	25	36	10′ 0″	18″, 24″, 30″, 36″	10′	1½ miles	Either side	10′ 0″	12′ 0″	40,000
1	35	....	15′ 0″	24″, 30″, 36″	6′	1¼ miles	Either side	10′ 0″	14′ 0″	48,000
1	....	50	15′ 0″	24″, 30″, 36″	6′	1¼ miles	Either side	10′ 0″	14′ 0″	47,000
1	35	....	15′ 0″	24″, 30″, 36″	6′	1¼ miles	Either side	10′ 0″	14′ 0″	50,000
1	....	50	15′ 0″	24″, 30″, 36‴	6′	1¼ miles	Either side	10′ 0″	14′ 0″	49,000
10	40	....	20′ 0″	24″, 30″, 36″, 48″ 60″, and 72″	3′	1 mile	Either side	10′ 0″	14′ 0″	66,000



Chicago Trench Excavator.
Figure 118.

Chicago (Austin) Trench Excavator Digging a Trench 26 inches wide and 15 feet deep.
Figure 119.

chains are made up of steel drop-forged links connected by cross bars and the steel cutters or scrapers. See Figs. 118 and 119.

The scrapers are made oval in shape and extend slightly beyond the sides of the chains to trim the side of the trench and give clearance for the cutter frame.

At the rear end of the inclined frame are two vertical bars, the lower ends of which are attached to the cutter frame. These bars have racks on one side, and are operated by pinions driven by gears. The lowering of these bars forces the excavating chain into the soil and furnishes a crowding motion for keeping the chain always against the face and bottom of the trench. The excavating chain is of the up-digging type, similar to all chain and wheel machines in general use at the present time. The cutters travel up along the face or head of the trench removing a thin slice of material as they move upward. At the top sprocket the buckets turn over and deposit the excavated material on a moving belt conveyor. The latter carries the material to one side of the trench and deposits it in a spoil bank. The depth of cut is regulated by raising and lowering the free end of the frame. When obstructions are met with in the trench, the chain may be raised over them and fed down into the earth on the other side. This excavator will dig trenches with widths of from 24 to 72 in. and up to a depth of 20 ft.

The front axle carries a sprocket wheel driven by a link-belt chain. The traction speed of the machine when in operation is given in Table XXV on page 259, and when moving over ordinary streets with the excavating wheel raised, the speed is about 1 mile per hour.

99a. Use in Illinois.—Two Chicago Sewer Excavators were used in Glencoe, Illinois for the excavation of trenches for a sewer system. The following gives a statement of the character of the work done:

15,500 lin. ft. of 8-in. pipe from 8- to 12-ft. cut.
5,600 lin. ft. of 10-in. pipe from 7- to 13-ft. cut.
250 lin. ft. of 12-in. pipe of about 13-ft. cut.
1,000 lin. ft. of 15-in. pipe of about 16-ft. cut.
4,700 lin. ft. of 18-in. pipe of shallow to 30-ft. cut.

The deepest cut of 30 ft. was made by grading down the street 3 to 4 ft. and then using the excavator for the next 25 ft. The remaining foot or two was removed by hand in the bottom of the trench and the earth thrown into the boom or back upon the laid

[1] Abstracted from Engineering-Contracting, April 5, 1911.

pipe. The width of trench cut was 33 in., the sides were cut smooth and vertical and braced with vertical plank and pack screws placed about 3 ft. apart in the deep trenches.

The soil excavated was a hard clay. The upper 15 ft. was a brownish clay with slight traces of sand. During the fall and winter months this material became hard, too hard to be dug by hand without the use of a pick. The excavator removed stones up to 1 ft. in size when wholly within the trench. When partly outside of the trench or when stones of larger size were encountered, they were removed by blasting. The ground was frozen at times up to a depth of from 14 to 16 in. but did not delay the work.

The work was carried on from August 1, 1910, to January 1, 1911. The following table gives the cost per day for the excavation of a trench 25 ft. deep, the laying of 18-in. pipe and back-filling.

1 foreman,	$8.00
Excavating machine including operator,	40.00
1 engineer,	4.00
1 fireman,	3.00
5 trenchmen @ $3,	15.00
20 laborers, back-filling @ $2.50,	50.00
2 teams @ $6,	12.00
Coal,	5.00
Repairs and sundry expenses,	10.00
Total,	$147.00
Length of trench excavated per day,	80 ft.
Cost of work,	$1.837 per lineal foot.

100. Buckeye Traction Ditcher.—This excavator is made by the Buckeye Traction Ditcher Company of Findlay, Ohio. A description of it is given in Division 2 of this chapter.

100a. Use in Colorado.—A Buckeye ditcher, equipped with a 28-in. by $7\frac{1}{2}$-ft. excavating-bucket chain, was used in the excavation of the earth section of a trench for a wooden water-pipe line in Greeley, Colorado.

The trench was 30 in. wide and 4 ft. deep and about $35\frac{1}{2}$ miles long. The material for 8 miles was gravel, occasionally cemented together and containing many stones. For the remainder of the distance, the material was a tough clay.

The following data gives the amount of excavation, cost of operation of ditcher and of excavation.

Total length of ditch excavated, 188,080 ft.
Total amount of excavation, 69,659 cu. yd.

Total time employed, 300 10-hour days.
Maximum excavation in gravel, per day, 370 cu. yd.
Maximum excavation in clay, per day, 925 cu. yd.
Average daily excavation, 232 cu. yd.
Average daily progress, 627 lin. ft.

Labor:

1 engineer @ $5 per day,	$1,500.00	
3 helpers @ $3 per day,	2,700.00	
Total labor cost,		$4200.00,

Fuel:

300 tons of coal @ $5,	$1,500.00

Miscellaneous:

Interest, depreciation and repairs @ $6,	$1,800.00
Total operating expense for 300 days,	$7,500.00

The cost per lineal foot of trench was as follows:

Engineer,	$0.008	
Helpers,	0.014	
Coal,	0.008	
Plant,	0.010	
Total cost per lineal foot,		$0.040

The cost per cubic yard of material excavated was as follows:

Engineer,	$0.021	
Helpers,	0.040	
Coal,	0.021	
Plant,	0.025	
Total cost per cubic yard,		$0.107

The above cost data do not include general expenses, back-filling, moving the ditcher to and from the job, etc.

The original cost of the machine was $5,200 and its working weight about 17 tons. The plant charges were estimated at about 30 per cent. per annum on the original cost and assuming the life of the machine as five years.

C. THE TRESTLE CABLE EXCAVATOR

101. General Description.—This type of excavator has been in use in this country during the past 30 years for the excavation and

filling of trenches for waterworks and sewer systems. It has become quite popular and is very efficient. Its advantages are the restriction of the work to the immediate area of the trench, the non-obstruction of a part of the street, allowing public traffic to go on, and the easy and safe method of operation.

The excavator consists of an overhead track supported by a series of trestles or bents, which rest on the ground or on a track. Along this track one or more carriers are moved by a cable, operated by a common double-drum friction hoisting engine. The carriers support tubs or buckets which are filled by the men in the trench, raised up simultaneously, moved horizontally as far as is desired and dumped by being tilted over the completed work or into wagons. The empty tubs are then returned to the excavation, lowered into the trench and replaced by other tubs, which are filled while the first set is being removed and emptied.

For trenches up to 60 in. in width a single track is generally used, but for wider trenches a double track is found to be economical. The whole framework rests on wheels, including the platform carrying the machinery and as soon as the excavation in one division of the trench is completed, the excavator moves forward by its own power to a new section of track. The framework can be arranged to work at railroad crossings without interference with trains and can also work around curves. The following table gives a description of the six standard sizes which are generally used. Figure 120 shows a six-bucket machine used in the excavation of a sewer trench in Winnipeg, Manitoba, Canada.

The manufacturers make the following recommendations as regards the sizes of machine to be used on different classes of work. "For trenches 6 ft. or less in width, and for all trenches where decided curves or right-angle turns are to be made, we recommend a single machine. Either our Four Traveler Machine ("Argus"), working a section 32 ft. long, or our Six Traveler Machine, ("Youth"), working a section 48 ft. long can be used, depending upon the rapidity with which the work is to be pushed. Where hard material is met with, it is often desirable with the Four Traveler Machine, to use three sets of tubs and work two bottoms or 64 ft. at a time, the tubs being hoisted first from one section and then from another. For trenches 6 ft. wide or wider we recommend our Eight Traveler Double Machine ("Bolt") as an all-around one, and often two bottoms are worked at a time with it, the tubs being taken first from one section and then from another, or it may be that one section is excavated to a convenient depth and

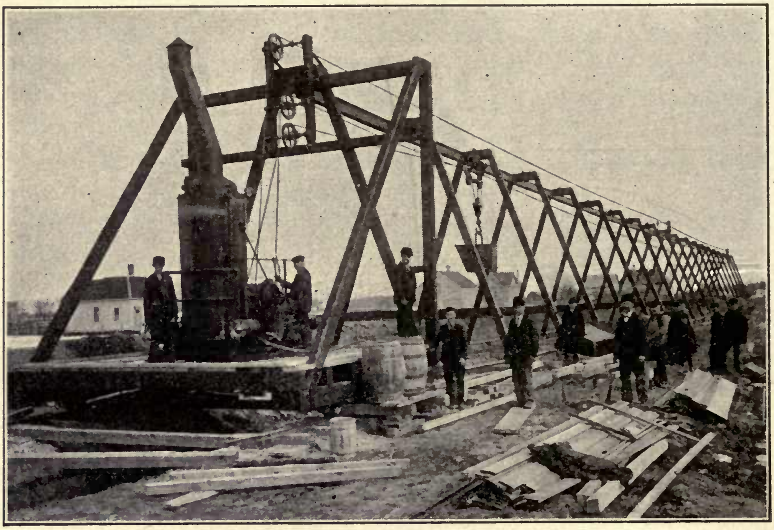
TABLE XXVI

SPECIFICATIONS OF TRESTLE CABLE EXCAVATORS

Telegraphic names	No. of tubs hoisted at a time	No. of tubs furnished with machine	Single or double upper track	Capacity of machine when run at moderate speed continuously for 10 hours, with tubs holding 5.5 cu. ft. each	Length of working section	Horse-power of double-drum, double-cylinder, hoisting engine required
Argus	4	12	Single	200 cu. yd.	192 ft.	20
Youth	6	18	Single	300 cu. yd.	288 ft.	20
Mail	8	24	Single	400 cu. yd.	320 ft.	30
Bolt	4	16	Double	300 cu. yd.	192 ft.	20
Xenia	6	24	Double	450 cu. yd.	288 ft.	20
Crown	8	32	Double	600 cu. yd.	320 ft.	30

then left for sheeting while the excavation is going on in the adjacent section. For a sand or gravel trench our Twelve Traveler Double Machine ("Xenia") is particularly adapted, and when great speed is desired in loose material our Sixteen Traveler Double Machine ("Crown") should be used."

For trenches through sand, gravel and clay, ranging in width from 8 or 12 ft. to 20 ft., the same company makes a special type of excavator known as the "Carson-Trainor Machine." This excavator is a hoisting and conveying device similar to the regular trench machine. A series of A-shaped trestles, resting on a track, support an overhead



Trestle Cable Excavator Operating in Sewer Trench Construction.
Figure 120.

trackway made up of a double channel beam. A traveler runs upon the lower flange of this girder, and is held in position or drawn backward and forward by an endless steel traversing rope attached to a special drum of the engine. The hoisting is done by a separate steel cable attached to the main drum of the engine. The machinery, consisting of the boiler and the engine, is mounted on a covered car, placed at the head of the excavation. The whole framework has a gage of 16 ft., a height from ground to peak of 20 ft., and a working section of 288 ft.

The following tables show the dimensions and capacities of the various sizes of machine:

TABLE XXVII

SPECIFICATIONS OF "CARSON-TRAINOR" EXCAVATOR

I. Single Traveler, Hoisting One Tub at a Time

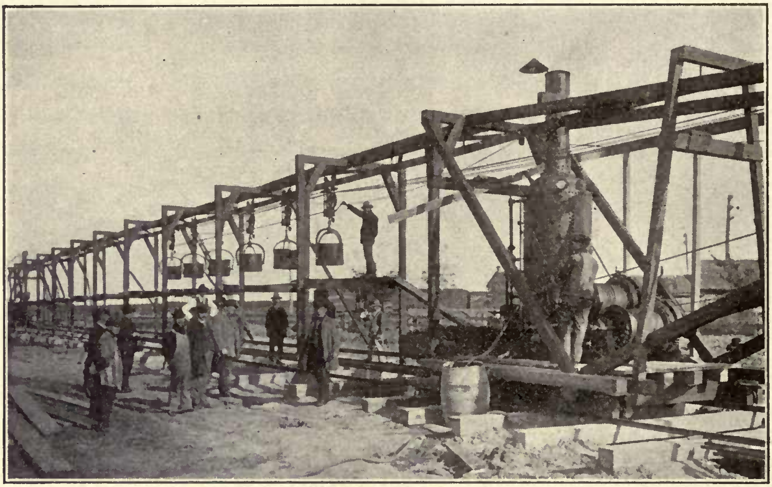
Name.	Distance between trestles	Length of machine	Height of trestles	No. of tubs used	Size of tubs	Lifting capacity of engine	Size of engine, double cylinders	Size boiler on engine bed	Size of car or engine house
Empire State...........	16 ft.	288 ft	20 ft.	5	27 cu. ft.	8,000 lb.	$8\frac{1}{4}\times 10$ in.	42×90 in.	16×18 ft.
Bay State..............	16 ft.	240 ft	20 ft.	5	21 or 27 cu. ft.	8,000 lb.	$8\frac{1}{4}\times 10$ in.	42×90 in.	16×18 ft.

II. Double Traveler, Hoisting Two Tubs at a Time

Name	Distance between trestles	Length of machine	Height of trestles	No. of tubs used	Size of tubs	Lifting capacity of engine	Size of engine, double cylinders	Size boiler on engine bed	Size of car or engine house
Chicago Limited........	16 or 18 ft.	288 ft	20 ft.	10	27 cu. ft.	8,000 lb.	$8\frac{1}{4}\times 10$ in.	42×90 in.	16×18 ft.
Philadelphia Special.....	16 or 18 ft.	240 ft	20 ft.	10	20 cu. ft.	8,000 lb.	$8\frac{1}{4}\times 10$ in.	42×90 in.	16×18 ft.

A view of a "Carson-Trainor Machine" excavating a sewer trench in Winnipeg, Manitoba, Canada, is shown in Fig. 121.

The following detailed specifications are for a single traveler machine equipped with tubs of 1 cu. yd. capacity and working 288 ft. of trench.



"Carson-Trainor" Trench Excavator on Sewer Trench Construction.
Figure 121.

ENGINE

This engine has $8\frac{1}{4}$-in. by 10-in. double cylinders, with cranks connected at an angle of 90 degrees, and is fitted with reversible link motion. The drums are of the Beekman patent friction type, one carries the hoisting rope, and the other is turned with a curved surface, and carries the endless rope. The endless rope is wrapped around the drum seven times—enough to secure sufficient friction to keep it from slipping in the opposite direction to that in which the drum is turning—and the ends are passed over sheave wheels on the trestles, and made fast to the front and rear of the traveling carriage.

The hoisting drum is entirely independent of the other, and, being of the same diameter, winds at the same rate of speed, and keeps the load at the same height while conveying, if desired. This drum also has a self-acting bank brake, by means of which the load can be held positively. It will thus be seen that this independent action f the drums gives the operator perfect command over the apparatus,

as he can use the drums together, or he can hold either of them and use the other. The reversing lever, friction, and brake levers are all brought to a convenient position, so that the operator can work all of them without difficulty. The engine is fitted with two winch heads.

BOILER

One vertical boiler, 42 in. diameter, by 90 in. high, containing 80 2-in. tubes, securely bolted and braced to bed plate of engine, and provided with safety-valve, steam-gage, water-gage, three gage-cocks, blow-off cock, injector, stack, steam-pipe connection to cylinders, with throttle-valve, exhaust-pipe into stack, set of grates, and two fire tools.

ENGINE CAR

The engine end of conveyor has a platform 18 ft. wide by 16 ft. long, built of eight pieces of 6 by 10 stock running crosswise, and four pieces running lengthwise, securely bolted together and mounted on four car wheels 15 in. diameter, with steel pins and cast bearings.

Flooring is of 2-in. plank, on which is erected a suitable house, built in sections and covered with two-ply roofing felt. The head trestle of the machine rests upon and is securely braced to this engine car, and is equipped with the necessary sheaves, shafts, etc.

TRESTLES

Nineteen A-shaped trestles, 16-ft. gage, made of 6 by 8 stock, with 4 by 10 headers, 20 ft. high, braced and bolted, and provided with castor frames, wheels, etc.

CONNECTING BARS

Thirty-eight connecting bars made of two and one-half inch tubular steel with connections and bolts complete.

HOISTING AND TRAVERSING ROPES

Hoisting and traversing ropes are of crucible steel $\frac{5}{8}$ in. diameter, and of sufficient length to operate machine and allow for hoisting from any point in a trench 35 ft. deep. One Manila rope of sufficient length to pull machine 100 ft. ahead is furnished.

THE RAILS

Enough T-rail, 25 lb. per yard, on which to place machine and move it ahead 100 ft.

GIRDERS

Twenty girders for upper track, made of solid, riveted, double-section, 15 lb. to the foot, 10-in. steel channel beams, with hangers and shackle plates.

HANGERS

The steel girders are suspended from the trestles and clamped together by our patented Mills adjustable angle-iron hangers, which, giving the girders a bottom bearing, prevent any unevenness in the track, and also keep the girders from twisting.

TRAVELER

The carriage or traveler is made of Norway iron, has eight single flange running wheels, and a 16-in. hoisting wheel, with steel bolts, pins, and shackles complete.

BLOCK

Fall block is of our heavy type with 16-in. sheave, and loose swivel hook, with safety handle attached.

TUBS

Five sheet-steel tubs of 27 cu. ft. capacity, with double bottoms, and provided with automatic catches. These tubs are self-dumping, when unlatched, and self-righting.

DUTY

This machine, when set up complete, is capable of hoisting 5,000 lb., at a speed of 225 ft. per minute, and conveying the same at a speed of 450 ft. per minute.

Under ordinary conditions, it will be profitable to use a trench machine when the work is of sufficient magnitude to pay for the investment in the plant and where the trenching will average over 9 ft. in depth. As the depth increases the cost of excavation by hand labor increases rapidly, while the cost by machine is nearly the same per linear foot of trench without regard to depth.

101a. Use in Connecticut.—A six-tub trench machine was used about 20 years ago in the construction of the boulevard sewer in New Haven, Connecticut. The following is the report of Mr. Henry H. Gladding, C. E., who had charge of this work:

DETAILS OF WORK AND CAPACITY OF MACHINE

Width of trench, 10 ft.
Depth of trench, 30 to 31 ft.
Material, clean sand.
Distance carried back, 208 ft.
Number of men shovelling, 6.
Engine, Lidgerwood, 20 h.p.
Steam pressure, 100 lb.
Number of upper tracks, 2.
Number of travellers, each track, 6.
Number of buckets, each track, 6.
Number of buckets in use, 18.
Number of buckets per trip, 6.
Ordinary load, per bucket, 4.2 cu. ft.
Ordinary load, per trip, 0.93 cu. yd.
Average time per trip, 1 min. 14 sec.
Number of trips per hour, 48.7.
Amount handled per hour, 45.3 cu. yd.
Length of day, 10 hours.
Deduct for moving engine ahead, adjusting buffer, tightening bolts, and all delays incidental to operating the machine, ½ hour.
Effective time per day, 9½ hours.
Capacity per day, 430 cu. yd.
Best time observed, 9 trips in 10 min.
Quickest trip observed, 1 min. 2 sec.

Frequent runs of four to five hours are made, stopping only to shift from one section to another.

Four hundred and thirty cubic yards per day is a fair, conservative estimate of the capacity of the machine under the conditions here existing.

It is based on a considerable number of observations when working at different stages from the surface to the full depth of the trench; the time in the middle third being somewhat better than the average of the top and bottom. The deepest part of the work has not yet been reached; it will exceed 40 ft.

Assuming nine trips in 10 minutes the best time observed, the output would be at the rate of 427 cu. yd. per day; this would be likely to occur only with the minimum vertical travel, and therefore only for a short time in each section. With this condition, and with all circumstances favorable, it might be possible to push the machine to a rate of 500 cu. yd. per day; but it is doubtful if any net increase in economy would result from a speed much in excess of the average given in this report, owing to the excessive wear and strain developed in the engine and framework, and also on account of the greater number of men required to fill and empty the buckets.

OPERATING EXPENSES, ETC.

Engineer,	$ 2.50 per day
Fireman,	1.50 per day
Six shovellers @ $1.50,	9.00 per day
Signal man,	1.50 per day
Dump man,	1.35 per day
$\frac{1}{2}$ ton of coal @ $3.80,	1.90 per day
Rent of machine,	10.00 per day
Rent of engine,	2.50 per day
Total,	$30.25 per day
Daily capacity of machine,	430 cu. yd.

Cost per cubic yard for shovelling into tubs, raising from an average depth of 17 ft., carrying back about 208 ft., 7 cents.

This conclusion is upon the supposition that the machine is running all the time, with no delay for sheathing and bracing; a condition never realized in practice.

In this particular instance it requires scarcely half as long to excavate a section as to tight-sheath, brace, and bulkhead the same as thoroughly as is demanded by the depth of the trench and the looseness of the material, five tier of sheathing being required.

During perhaps one-half of this idle time, which comes in short spells, the shovellers, signal man, and dump man can be employed on other work, thus deducting, say, $2.75 from the daily expense for handling the sand; so that the actual cost per cubic yard, reckoning only half duty from the machine, would be $27.50 ÷ 215 = 13 cents.

October 16 the trench was advancing an average distance of $15\frac{4}{10}$ ft. per day, and had a depth of 37 ft., with the constant width of 10 ft., making the daily excavation about 211 cu. yd., nearly the same as deduced above.

While it is hardly practicable to obtain a very precise rating of the performance of such a machine, I believe the figures and deductions given herewith are substantially correct.

D. THE TOWER CABLEWAY

102. General Description.—The tower cableway excavator is a hoisting and conveying device using a suspended wire cable as a trackway. The steel cable or rope is fastened at each end to a tower or trestle about 30 ft. in height. The towers are placed about 250 ft. apart so that 200 ft. of sewer can be completed at one set up. Upon the cable one or more travelers are operated. They are held in position or moved backward and forward by an endless steel traversing rope attached to a special drum of the engine. The hoisting is done by an independent steel rope operated by the regular drum of the engine. At one end of the excavation is placed the machinery, consisting of the boiler and engine, mounted on a covered car which moves along on a track.

103. Carson-Lidgerwood Cableway.—This excavator is made in the four sizes given in the following table:

TABLE XXVIII

SINGLE TRAVELER, HOISTING ONE TUB AT A TIME

Yard, three-quarter yard, or half yard tubs will be furnished as desired

Telegraphic letter	Capacity in ten hours	Distance between trestles	Height of trestles	Number of tubs used	Size of tubs	Lifting capacity	Size of engine, double cylinder	Size boiler on engine bed	Size car or engine house
E	From 300 to 450 cu. yd.	250 ft......	25 ft......	5	27 cu. ft...	5,000 lb.....	$8\frac{1}{4} \times 10$ in...	42×90 in...	10×16 ft.
F		300 ft......	30 ft......	5	27 cu. ft..	5,000 lb.....	$8\frac{1}{4} \times 10$ in...	42×90 in...	10×16 ft.
G		350 ft......	35 ft......	5	27 cu. ft..	5,000 lb.....	$8\frac{1}{4} \times 10$ in...	42×90 in...	10×16 ft.
H		400 ft......	40 ft......	5	27 cu. ft..	5,000 lb.....	$8\frac{1}{4} \times 10$ in...	42×90 in...	10×16 ft.

The following specifications will give a detailed description of the design and construction of this excavator:

Single traveler, 300-ft. span. Tubs of 1 cu. yd. capacity.

ENGINE

The engine has $8\frac{1}{4} \times 10$-in. double cylinders, with cranks connected at an angle of 90 degrees, and is fitted with reversible link motion. The drums are of the Beekman patent friction type, one carrying the hoisting rope, and the other is turned with a curved surface and carries the endless rope. The endless rope is wrapped around the drum five or more times—enough to secure sufficient friction to keep it from slipping in the opposite direction to that in which the drum is turning—and the ends are passed over sheave wheels on the trestles and made fast to the front and rear of the traveling carriage.

The hoisting drum is entirely independent of the other, and, being of the same diameter, winds at the same rate of speed, and keeps the load at the same height while conveying, if so desired. This drum also has a self-acting band brake, by means of which the load can be held positively. It will thus be seen that this independent action of the drums gives the operator perfect command over the apparatus, as he can use the drums together, or he can hold either of them, and use the other. The reversing lever, friction, and brake levers are all brought to a convenient position, so that the operator can work all of them without difficulty. The engine is fitted with two winch heads.

BOILER

One vertical boiler 42 in. diameter by 90 in. high, containing 80 2-in. tubes, securely bolted and braced to bed plate of engine, and provided with safety-valve, steam-gage, water-gage, three gage-cocks, blow-off cock, injector, stack, steam-pipe connection to cylinders with throttle-valve, exhaust-pipe into stack, set of grates and three fire tools.

CABLE

The main cable is of crucible steel, $1\frac{1}{2}$ in. diameter, and sufficiently long to allow for a span of 300 ft. between trestles, and to reach anchors placed 60 ft. from each trestle, it is provided with four loops each 26 ft. long, with thimble spliced in each end.

Hoisting and traversing ropes are of crucible, steel $\frac{5}{8}$ in. diameter,

and of sufficient length to operate machine and allow for a trench 35 ft. deep.

One turnbuckle, $2\frac{1}{4}$ in. diameter, 30 in. long, is placed at one end of cable to take up slack.

TRAVELER

The traveler is made of $\frac{5}{8} \times 3$ in. wrought iron, securely bolted and braced, with 12-in. top sheaves, and 16-in. hoisting sheave.

It has one or more patented fall rope carriers with suitable attachments and fittings.

One fall block with 16 in. sheave and substantial hook, with safety handle attached.

TUBS

Five sheet-steel tubs of 27 cu. ft. capacity, with double bottoms, and provided with automatic catches.

ENGINE HOUSE

Platform of engine house is 10 ft. wide by 16 ft. long, built of eight pieces of 6×10 spruce running crosswise, and four pieces of spruce running lengthwise, securely bolted together and mounted on four car wheels, 15 in. in diameter, with steel pins and cast bearings.

Flooring is of spruce 2 in. thick, on which is erected a suitable house built in sections, and covered with two-ply roofing felt. Six pieces of 25-lb. T-rail with fishplates and spikes.

TRESTLES

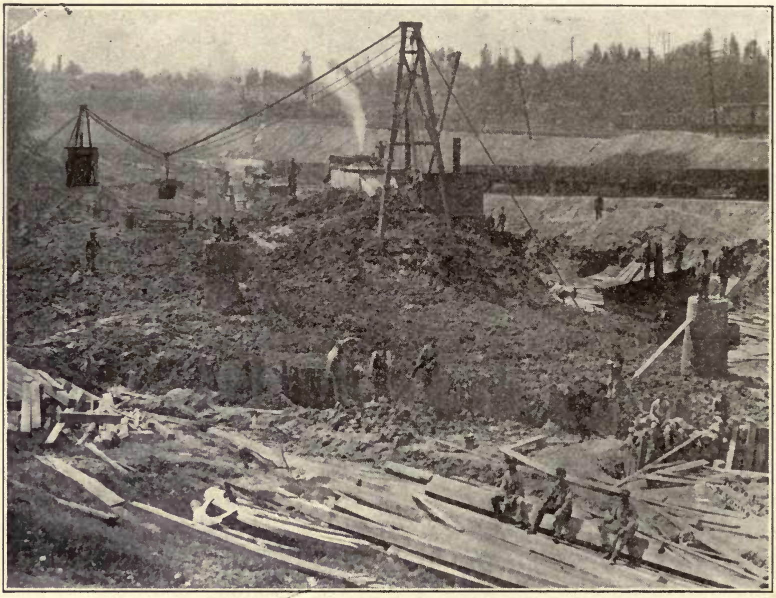
Two spruce trestles made of 8×10, 30 ft. high, braced, bolted, and strapped, and provided with saddles, sheaves, shafts, eyebolts, galvanized guys 1 in. in diameter, of sufficient length to hold frames in position, clips and shackles.

DUTY

This cableway when set up complete is capable of hoisting 5,000 lb. at a speed of 225 ft. per minute, and of conveying same at a speed of 450 ft. per minute.

Figure 122 shows a cableway excavating sewer trench at St. Joseph, Missouri.

103a. Use in Washington, D.C.—The following report is given to show the use of one of these cableways, for the excavation of a sewer trench in Washington, D. C., about 18 years ago (1895).



Cableway Excavator Digging a Sewer Trench.
Figure 122.

General Description of the Work

The Easby's Point sewer for about 1,100 ft. from the outlet is D-shaped, 11 ft. 3 in. in width and 11 ft. 3 in. in height, and rests on a pile foundation. This is followed by a circular section 11 ft. 3 in. in diameter for a distance of about 2,400 ft., then about 1,000 ft. of 10 ft. 6 in., then about 1,600 ft. of 9 ft. 6 in.

The first 1,200 ft. of the 11 ft. 3 in. circular is in a cut varying from 12 ft. to 40 ft. in depth, with about 10 ft. of clay and rotten rock on top of solid rock. This rock, while very hard, is badly broken up by seams running in every direction and at all angles with the horizon.

In spite of the most careful blasting and heavy bracing, the line of fracture would follow these seams to the surface, bringing in large masses outside the regular width of excavation. About 1,000 lin. ft. of this work were done by steam derricks, and in places the slides were so extensive that the top width was more than 50 ft. The normal width of the trench was 18 ft.

As it was determined to increase the plant, a study of the different forms of trench machines was made, and the trench machines spanning the ditch were rejected for the following reasons.

1. Experience had shown that it would not be safe to do the heavy blasting required under them.

2. On account of the width of the trench, 18 ft., heavy timbering would be required to carry the machine, and in event of a slide the machine would be almost certain to go into the ditch.

3. As about 3,000 ft. of the remaining distance would be through made ground where the banks could not be depended upon, it was not thought advisable to put any extra weight upon them or to subject them to the vibrations which would be occasioned by a machine spanning the trench.

As a cableway was not open to any of these objections, an order was given for one of the following:

General Dimensions

Length between end frames, 300 ft.
Total length between anchorages, 430 ft.
Height of frames, 32 ft.
Diameter of main cable (steel), $1\frac{1}{2}$ in.

Cylinder Dimensions

Engine, Lidgerwood, $8\frac{1}{4} \times 10$ in.
Speed of hoisting, 250 ft. per minute.
Speed of conveying, 400 ft. per minute.
Lifting capacity, 5,000 lb.
Size of buckets, 1 cu. yd.

Character and Amount of Work

Width of trench, 18 ft.
Depth of lower shelf of trench on which cableway was started, 15 ft.
Distance of carriage, 150 ft.
Number of trips per hour, 35.
Number of hours per day, 8.
Number of cubic yards excavated per day, 280.

The material was cemented gravel and rotten rock which could have been removed cheaper by blasting than by picking.

Operating Expenses per Day

Engineer,	$2.00
Fireman,	1.25
Signal man,	1.00
Two dumpers @ $1	2.00
Coal, oil, and waste,	1.50
Interest and maintenance (estimated),	7.00
	$14.75
Cost of picking and shoveling into tubs, 30 men, at $1,	$30.00
	$44.75

Cost of picking, shoveling into tubs, hoisting from trench 15 ft. deep, conveying 150 ft. and dumping into wagons, 16 cents per cubic yard.

Cost for hoisting, conveying, and dumping, $5\frac{3}{10}$ cents per cubic yard.

At the same time the excavating was going on, bracing and sheathing was being done, so that this represents what can be done in the regular order of working, and was not a spurt to see what the machine could do when pressed. In fact, none of the men knew that the machine was being timed.

The conditions under which the machine was working were not favorable for making a record, as the bracing in the trench was too close together for the size of tub used. The engineer was a new man at the machine, although used to running a hoisting engine. Dumping into wagons consumed much more time than would have been required to dump on the work.

I think 300 cu. yd. can easily be handled in a day of eight hours in fairly good material in regular work, and no doubt under favorable circumstances the machine could be pushed much beyond this limit for a short time.

The machine has been at work about three weeks, but owing to the depth of the trench, 30 to 40 ft., and the quantity of rock to be removed, it has not been moved. I am therefore unable to say how long this would take, but think the machine could be taken down, moved, and set up in a day or less.

Since the engine was fairly in working order the machine has not been stopped 10 minutes for repairs or adjustment.

(Signed) FRANK P. DAVIS,
Civil Engineer.

104. S. Flory Cableway.—The S. Flory Mfg. Co. of Bangor, Pa., has been supplying cableways for the slate quarries of eastern Pennsylvania for the last 30 years. Recently, it has supplied a system for use on trench excavation. Fig. 123 shows a cableway of 400-ft. span, being used in the construction of a large trunk sewer.

A special engine is used, geared for high speed when traversing and lower speed for hoisting. The hoisting rope is taken over the front sheave in the carriage, around the fall block and over the back sheave in the carriage and then fastened back to the end tower. This eliminates the fall rope carriers and forms a two-part hoisting line.

In operation, the bucket is filled and then raised above the excavation hy the hoisting drum, which is then thrown out of gear and held with a brake. The traversing line is then put in operation and conveyed in either direction. When the bucket has reached the place of disposal, the traversing drum is thrown out of gear and the bucket lowered by means of the brake band on the hoisting drum.

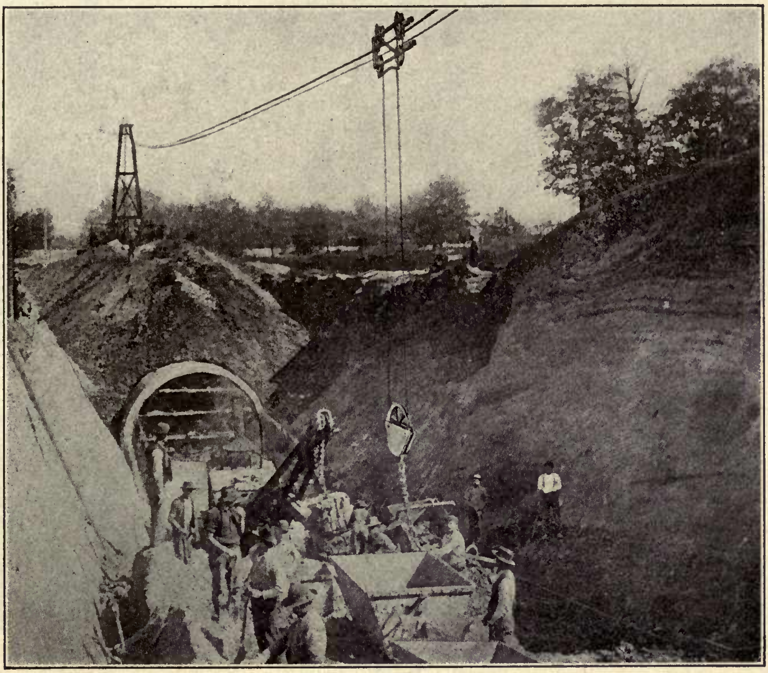
E. THE TRESTLE TRACK EXCAVATOR

105. General Description.—This type of excavator is similar in its method of operation to the trestle cable excavator, described under division C. Instead of the buckets being suspended from carriers

which move along a track, they are carried along on the platform of a car or carriage, which moves along a track resting on the tops of the trestles.

106. Potter Trench Machine.—This excavator is manufactured by the Potter Manufacturing Company of Indianapolis, Indiana.

A series of light steel trestles of trapezoidal shape are spaced about 10 ft. 6 in. on centers and are about 8 ft. high. These trestles are



Cableway used on Construction of Large Sewer.
Figure 123.

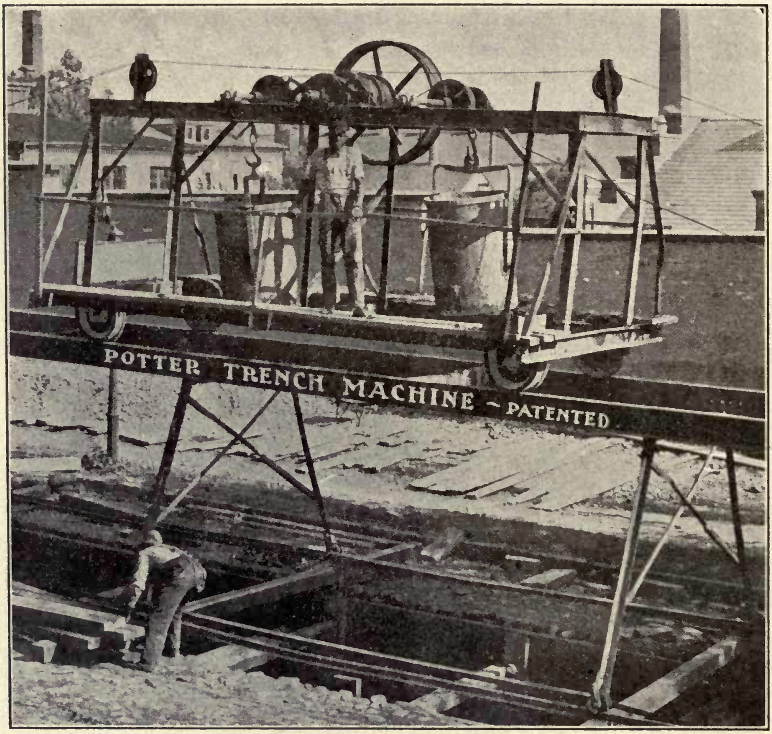
mounted on double-flanged wheels, which run on rails, laid on either side of the trench. On the tops of the trestles are framed two channels which form a continuous track for a carriage to run on.

The car or carriage is a steel-framed structure supported on four wheels, which run on the trestle track, and is operated by means of cables from the hoisting engine and also from the hoist. See Fig. 124.

Each car operates two tilting buckets which are filled by men in the trench, raised by the hoist to the car, and then carried along to the

dumping place. Two men on the car operate the hoist, which can raise or lower either one or both of the buckets at a time. The buckets are made in three sizes; $\frac{1}{3}$, $\frac{2}{3}$ and 1 cu. yd. capacities.

At one end of the trestle is placed a housed-in platform containing



Trestle Track Excavator.
Figure 124.

the boiler and engine. The platform is mounted on wheels and the whole framework can be moved along under its own power. The machine covers 272 ft. of trench at a time.

The machine requires three men for operation, one to operate the hoisting engine and two on the carriage.

106a. Use in Illinois.[1]—A Potter Trench Machine was used during the season of 1907 in the excavation of a large sewer trench in Chicago, Illinois.

[1] Abstracted from Engineering-Contracting, October 9, 1907.

The trench had a width of 21 ft. and an average depth of 30.5 ft. The materials excavated were, a top layer of black soil, then 15 ft. of soft blue clay, 6 to 8 ft. of stiff blue clay, 1 ft. of sandy loam and finally about 2 ft. of hard blue clay.

The trench machine followed a derrick crane and excavated the last 12 to 14 ft. in depth. Six buckets with a capacity of $\frac{1}{2}$ cu. yd. each were used and so arranged that four were in the trench being filled while the remaining two were being carried away on the carriage and dumped.

The following table gives the cost of excavation on the basis of an eight-hour working day:

Labor:		
1 engineer,	$ 6.00	
1 fireman,	2.50	
1 carriage operator,	3.25	
1 carriage helper,	2.50	
20 laborers in trench, @ $2.75,	55.00	
1 laborer on dump,	2.75	
1 foreman,	3.50	
Total labor cost,		$75.50
Fuel:		
$\frac{1}{2}$ ton coal @ $5,		$2.50
Rent of machine @ $125 per month,		$4.80
Total,		$82.80
Average daily excavation,		175 cu. yd.

Average cost of excavation; $82.80 ÷ 175 = $0.47 per cubic yard.

SECTION II. TILE TRENCH EXCAVATORS

110. **Field of Work.**—Until about 11 years ago (1902), most of the trench excavation for drain tile was made by hand labor. As this class of drainage work became more general, especially in the states of Illinois, Iowa and Minnesota, various forms of machinery were devised to meet the increased need. At the present time, there are at least three tile ditchers which have demonstrated their efficiency under favorable conditions. Where the ground is fairly level, free from large, heavy obstructions and not too hard, these machines will be found very efficient and more economical than hand labor.

111. **The Buckeye Tile Ditcher.**—The Buckeye Tile Ditcher is a traction engine on the rear end of which is hinged a frame which

carries an excavating wheel provided with buckets placed around its periphery. These machines are made in a number of sizes as given by the following table:

Number	Size	Approximate wt. in tons
1	$11\frac{1}{2}$ in. $\times 4\frac{1}{2}$ ft.	$5\frac{1}{2}$
2	$14\frac{1}{2}$ in. $\times 4\frac{1}{2}$ ft.	$6\frac{1}{2}$
3	15 in. $\times 5\frac{1}{2}$ ft.	$8\frac{1}{2}$
4	20 in. $\times 5\frac{1}{2}$ ft.	11
5	20 in. $\times 7\frac{1}{2}$ ft.	$13\frac{1}{2}$
7	24 in. $\times 7\frac{1}{2}$ ft.	15
8	28 in. $\times 7\frac{1}{2}$ ft.	18
9	32 in. $\times 7\frac{1}{2}$ ft.	$20\frac{1}{2}$
10	36 in. $\times 7\frac{1}{2}$ ft.	24
11	42 in. $\times 7\frac{1}{2}$ ft.	27
12	48 in. $\times 7\frac{1}{2}$ ft.	29
13	54 in. $\times 7\frac{1}{2}$ ft.	32

These various numbers are all made alike, differing only in size and a detailed description of No. 2 will suffice for all.

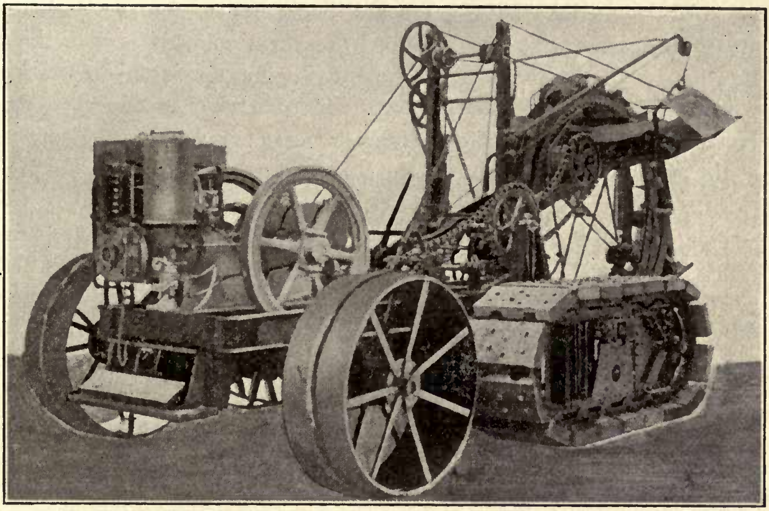
This machine will excavate a trench $14\frac{1}{2}$ in. wide and $4\frac{1}{2}$ ft. deep. It consists of a steel frame 12 ft. long and 4 ft. wide supported on four wide steel wheels. The wheel centers of each pair are 6 ft. 4 in. apart and the axles are 7 ft. on centers. As will be seen from an inspection of Fig. 125, the rear axle has a sprocket which carries a chain belt operated by a set of gears on the engine.

On the front end of the truck is placed an 8-h.p. vertical boiler, which furnishes steam for the 6-h.p. single engine located directly back of it.

Attached to the rear end of the truck is the wheel frame, connected with a cross-bar, which moves vertically between two posts. The front part of the frame can be raised and lowered by means of a ratchet wheel. The rear part of the frame is connected to sheaves at the top of the vertical frame by cables, which may be operated to raise the wheel from the ground when it is desired to move the machine from one trench to another.

The wheel frame carries an open wheel 8 ft. in diameter and $12\frac{1}{2}$ in. wide. This wheel has no axle, but revolves by means of four anti-friction wheels placed inside the rim. See (8) and (9) in Fig. 126.

On the outer rim of the wheel are placed 14 buckets as shown by



Buckeye Traction Ditcher.
Figure 125.

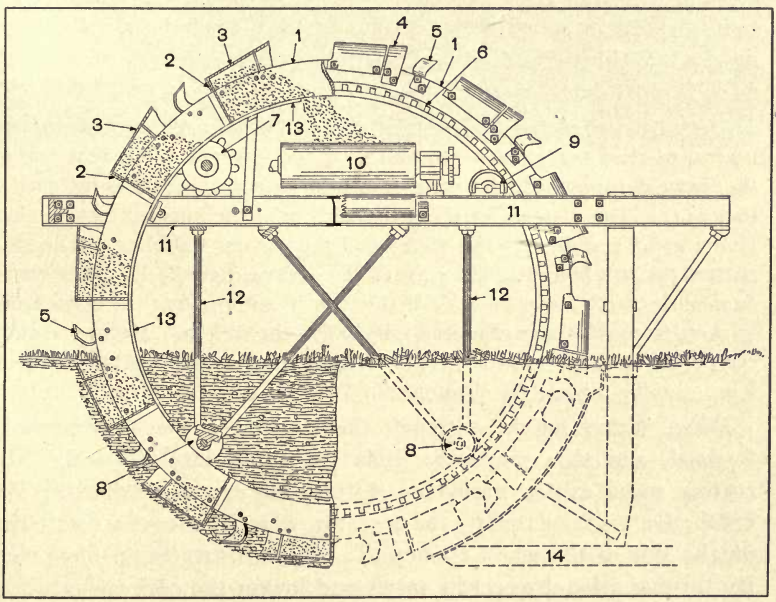


Diagram of Excavating Wheel of Buckeye Traction Ditcher.
Figure 126.

(3). These buckets have a top and back, but no bottom.[1] They are shaped somewhat like the bowl of a drag-scraper; and, in fact, they act very much like a drag-scraper in digging; for as the excavating wheel revolves, each bucket cuts off a slice of earth of its own capacity. Now, this earth would fall out when the bucket rises above the surface of the ground if it were not for the high-carbon steel arc, marked (13) in Fig. 126. This arc does not revolve, as it is not fastened to the wheel. When an excavating bucket reaches the end of the arc near the top of the wheel, the dirt falls out of the bucket upon the belt conveyor. This conveyor, which is marked (10), carries the dirt off outside of the trench where it piles up. It will be noted that the dirt slides over the stationary arc (13) only a short distance near the top of the wheel, hence there is very little wear on the arc. As we have said, the excavating wheel does not have an axle; it is made to revolve by a pair of driving sprockets (7), which mesh with the segmental gearing (6). It should be noted that the driving sprocket (7) is directly above the point where the earth is being excavated, so that the force is applied directly. Thus the weight of the excavating wheel is far less than would be necessary were it driven from an axle, involving also great torsional strain. What is even more important, the excavating wheel can dig into the ground to a depth of nearly two-thirds its diameter, so that with a comparatively small wheel a great depth of trench is secured.

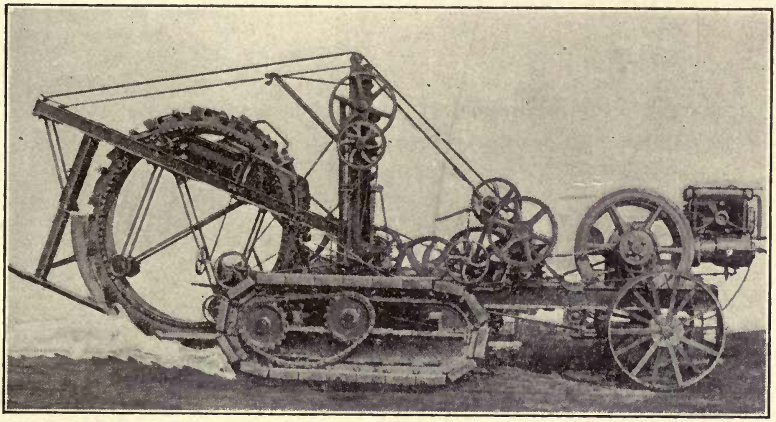
"It will be seen that the excavating wheel is supported between two beams, marked (11), which can be raised and lowered. The rear end of the frame is supported by a post, to the lower end of which is fastened a shoe (14). This shoe slides along the bottom of the finished trench, thus giving great stability to the wheel and preventing wabbling. The side cutters (5), are bolted to the rims of the excavating wheel. They serve to slice the earth from the sides of the trench, and prevent the excavating buckets from sticking or becoming bound in the trench. Moreover, they scrape all the dirt toward the center of the trench, where the buckets pick it up, leaving a perfectly clean cut."

When excavating in a trench the machine moves continuously forward, and thus gradually feeds the wheel into the soil. The cutting speed can be varied by shifting the sprocket wheels. The depth of cut is regulated by the operator, who sights over a sight-arm, on the side of the wheel frame, at a series of targets on flag-poles. By turning a hand wheel he raises and lowers the excavating wheel until the sight-arm is at the proper level. The alignment is kept

[1] This description and Fig. 126 are taken from the catalogue of the Buckeye Traction Ditcher Co.

by lining in the centers of the front and rear wheels with the flag-poles. Where the ground is fairly level, a true line and grade can be easily kept, but when the surface is rolling or uneven, constant attention is necessary.

The fuel is kept in a box in front of the boiler and the water in a tank under the engine. Two men are generally necessary to run a steam-operated ditcher, one to tend the boiler and engine and the other to operate the excavating wheel. It is often more economical of fuel and labor to use a machine operated by a gasoline engine. Such a tile ditcher is shown in Fig. 127.



Buckeye Traction Ditcher with Gasoline Power.
Figure 127.

The traction speed of the machine when not digging is 1 mile per hour but on account of the necessary stops to take on coal and water, to fill dead furrows, etc., an average speed of $\frac{3}{4}$ mile per hour is all that can be attained.

111a. Use in Minnesota.[1]—The following record of tile trenching on the Northwest Experiment farm of the University of Minnesota at Crookston, Minnesota. This work was done in 1903 by a Buckeye traction ditcher of the size described in the previous article. The machine cost $1,400 and has since been improved so that this record is rather conservative. It is also evident from the report given in the Bulletin, that the machine was poorly operated.

The natural conditions on this farm were generally favorable for a

[1] Abstracted from Bulletin 110, Northwest Experiment Farm, University of Minnesota.

machine trencher. The surface was uniformly level and the soil was free from stones, roots and sloughs. The surface was almost entirely covered with sod and in many places the soil was sticky and "gumbo" in character. The trenches had an average depth of $4\frac{1}{2}$ ft.

Example 1.—The machine dug 8,750 ft. of trench in 10 working days, making an average progress of 875 ft. per day.

Following is a table giving the cost of excavation and tile laying:

	Cost per 100 ft.	
Labor of operating machine,	\$0.457	
Coal,	0.188	
Water,	0.126	
Oil,	0.012	
Repairs,	0.112	
Cost of excavation,		\$0.895
Laying tile,	\$0.183	
Blinding,	0.048	
Incidentals,	0.092	
Cost of laying, etc.,		\$0.323
Total cost of tile work,		\$1.218

Example 2.—In this case the soil conditions were more favorable than in Example 1, as the sod was thin and the soil dry. The following table is based on a total length of trench excavation of 10,450 ft.

	Cost per 100 ft.	
Labor of operating machine,	\$0.409	
Coal,	0.190	
Water,	0.087	
Oil,	0.010	
Repairs,	0.100	
Cost of excavation,		\$0.796
Laying tile,	\$0.212	
Blinding,	0.053	
Incidentals,	0.015	
Cost of laying, etc.,		\$0.280
Total cost of tile work,		\$1.076

Example 3.—In this case the soil was generally wet and covered with a broken sod. The following table is based on a total length of excavated trench of 14,298 ft.

	Cost per 100 ft.	
Labor of operating machine,	$0.516	
Coal,	0.263	
Water,	0.126	
Oil,	0.014	
Repairs,	0.200	
Cost of excavation,		$1.119
Laying tile,	$0.235	
Blinding,	0.062	
Incidentals,	0.012	
Cost of laying, etc.,		$0.309
Total cost of tile work,		$1.428

The average cost of all the machine work done was $1.25 per 100 ft., while the cost of trench work done by hand labor on the same farm, was $3.88 per 100 ft. This comparison of costs shows the advantage of a machine excavator for title trench work, even under the adverse conditions of an early type of ditcher and inefficient operation.

111b. Use in Ohio.—During the year 1910 a Buckeye ditcher equipped with a gasoline engine and capable of digging a trench $14\frac{1}{2}$ in. wide by $4\frac{1}{2}$ ft. deep (see Fig. 127) has been used near New London, Ohio. About 12 miles of trench were dug, with an average depth of $2\frac{1}{2}$ ft. The soil excavated was loam and clay, which was rather hard during the dry season and sticky when wet. The excavator was equipped with apron or caterpillar tractions and passed through several swamps. The following table gives the average cost of excavation for the season:

	Cost per rod
Operator,	$0.03
Gasoline @ 13 cents per gallon,	0.018
Repairs,	0.024
Oil and grease,	0.001
Total cost per rod excavated,	$0.073

One man was found sufficient to operate the machine satisfactorily. The average cost of excavation of tile trenches by hand in the same locality the previous season was 35 cents per rod.

Near Fremont, Ohio, the following record was kept of the use of a Buckeye ditcher during an 11-hour working day in September,

1910. The excavator was a steam-power machine with a capacity of $11\frac{1}{2}$ in. wide by $4\frac{1}{2}$ ft. deep. See Fig. 125. The total excavation made was 270 rods of trench with an average depth of 2 ft. 4 in.

The following table gives the cost of the work for the 11-hour day:

Operator,	\$2.50
Fireman,	1.50
Cylinder oil,	0.23
Machine oil,	0.10
Total cost of excavation,	\$4.33

Fuel and water were supplied by the land owner.

111c. Use in Iowa.—Near Dawson, Iowa, a Buckeye ditcher, with steam power and with a capacity of 15 in. by $5\frac{1}{2}$ ft., excavated 110 rods of trench to an average depth of 4 ft. during two 7-hour working days. The operating cost was as follows:

	Cost per day
Operator,	\$2.50
Fireman,	2.50
Coal, $\frac{1}{2}$ ton ; @\$3.25,	1.625
Oil,	0.125
Total cost per day,	\$6.750

Average daily excavation, 55 rods.

Cost of excavation per rod, \$6.75 ÷ 55 = \$0.123

111d. Use in Kansas.—Near Oswego, Kansas, a Buckeye ditcher with steam equipment and capacity of $11\frac{1}{2}$ in. by $4\frac{1}{2}$ ft. operated successfully in various soils for several seasons. The average excavation made in a clay loam soil under favorable conditions was about 60 rods of trench 3 ft. in depth in three hours.

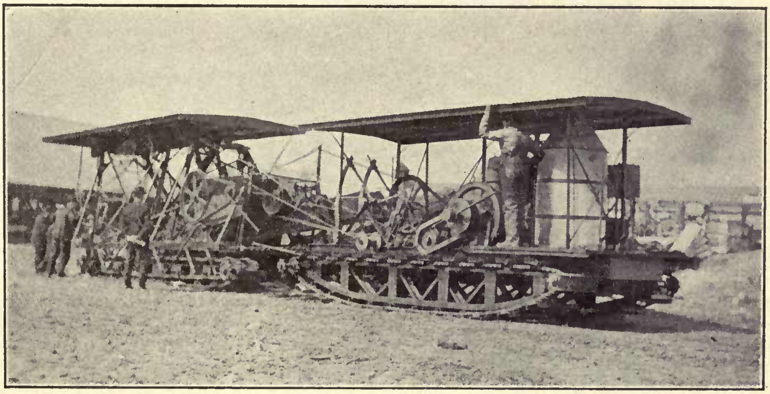
The following is an estimate of the cost of excavation per working day of eight hours.

Operator,	\$3.00
Fireman,	1.00
Coal, $\frac{1}{4}$ ton @ \$4,	1.00
Oil and waste,	0.15
Total cost per day,	\$5.15

112. Hovland Tile Ditcher.—The Hovland tile ditcher made by the St. Paul Machinery Manufacturing Company of St. Paul, Minnesota, is a machine which not only excavates a trench, but also automatically lays tile up to 12-in. diameter.

This excavator is made in two parts, the front traction platform which carries the power equipment and the rear traction platform which carries the excavating chain. Both platforms are made of a steel framework supported on two continuous apron tractors. In order to afford a better grip on the surface, steel channels with the flanges out, are used instead of the ordinary wooden blocks. The length of each traction is 22 ft. and the width out to out of tractions is 10 ft. A complete outfit is shown in Fig. 128.

The main or rear tractor consists of a platform 26 ft. long and 10 ft. wide, which supports a steel framework. From this is suspended the excavating chain and its supporting framework. The latter consists of a small upper wheel and a large lower wheel or drum, about which the



Hovland Tile Ditcher.
Figure 128.

excavating chain revolves. The larger and lower drum is suspended by chains from the rear of the framework and can be raised and lowered by a gear-operated shaft. The upper and smaller wheel is on a shaft which is chain driven from the engine located on the forward tractor. A small wheel is suspended from a gear-operated shaft near the center of the top of the framework and takes up the slack of the upper portion of the chain. The excavating chain consists of two continuous chains which carry a continuous set of hinged links. To the vertical sections of these links may be bolted knives or cutters of any width from 5 in. to 30 in. These links are so hinged, that when a cutter strikes a stone or other obstruction in a trench the chain gives, and the cutter slides over the stone without injury. Above the

upper wheel, which is toothed on each side to receive the side chains, is placed an automatic cleaning device. This consists of a projecting arm so placed that its outer end scrapes over the surface of each bucket as it reaches the top wheel. The excavated material is thus cleaned off the cutter and falls upon a continuous belt conveyor located underneath the excavating chain at its upper end. Fig. 129 and 130 show in a diagrammatic form how the excavating chain is supported and operated.

An adjustable steel-frame curbing can be fastened to the rear of the excavating tractor and drawn along the completed trench. This curbing is adjusted to the width of the trench and made high enough

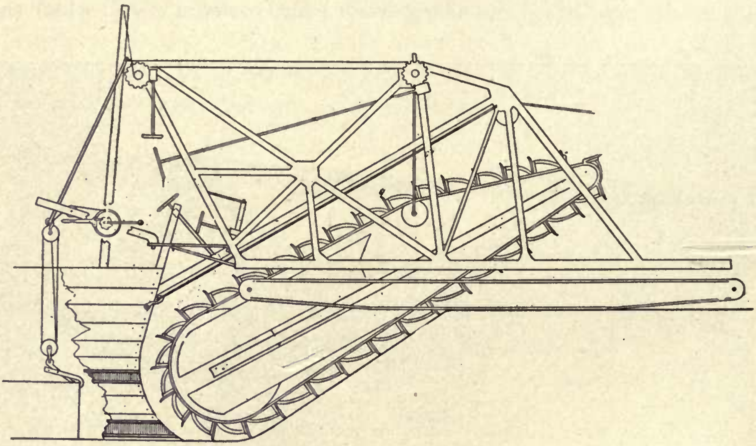


Diagram of Excavating Chain of Hovland Tile Ditcher.
Figure 129.

to project above the ground surface. A steel spout is placed on the inner and curved portion and as the machine progresses, a man places the tile in at the top of the spout, which is curved so as to allow the tile to slide out in place along the bottom of the finished trench.

The forward tractor carries the power equipment consisting of a three-cylinder, vertical, gasoline engine. The main shaft of the engine is connected by sprocket chains to the driving shafts of the tractions of the excavating belt and the belt conveyor. Two men are required to operate the machine, one for the engine and the other for the excavator.

Two sizes of machine are made, one called a "single-wheel" machine and the other a "double-wheel" machine. The former has a 45-h.p., three-cylinder, gasoline engine and can excavate a trench with a width

of from 10 to 20 in. and depth of from 3 to 12 ft. The latter has a 60-h.p., four-cylinder, gasoline engine and can excavate a trench with a width of from 14 to 30 in. and a depth of from 3 to 6 ft. The machines when excavating can move at a speed varying from 25 ft. to 100 ft. per hour depending on the depth of trench and soil conditions. When moving across country, the machines can move at an average rate of about three-fourths of a mile per hour.

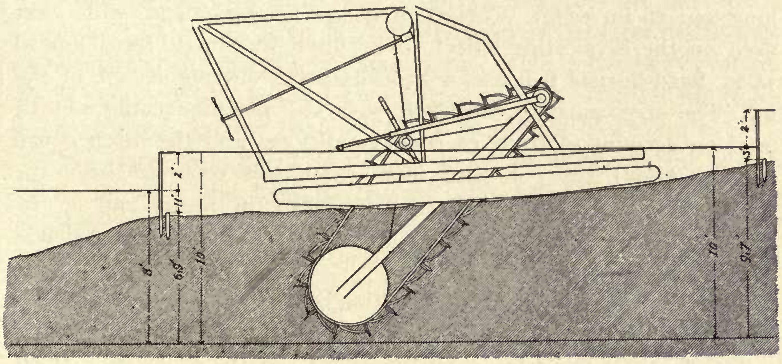


Diagram showing the Cperation of the Excavating Chain of the Hovland Tile Ditcher.
Figure 130.

112a. Use in Minnesota.—During the summer of 1910, a Hovland tile ditcher operated by a 45-h.p. gasoline engine, was used for the excavation of a system of county ditches in Lac Qui Parle County, Minnesota. The fastest speed made by the machine while excavating was 100 ft. in 35 minutes, while the slowest speed was about 120 ft. per hour.

The country in which the work was done was of a rolling character. The surface was dotted with pot holes from 2 to 20 acres in area, many of them filled with water to the depth of from 2 in. to 4 ft. The soil was a brown silt and a black-clay loam, from 2 to 5 ft. deep, underlaid with a sandy-clay sub-soil containing a very large percentage of sand. A few field stones were encountered and in places a very hard clay sub-soil was found. The latter was not difficult to excavate with the ditcher. The soil had a tendency to cave when wet or when the depth of the ditch was over 6 ft.

The equipment for this work and its cost is given in the following table:

1 "single-wheel" Hovland tile ditcher,	$5000.00
3 shacks on wagons,	375.00
Equipment for shacks,	100.00
1 team, wagon, harness and light buggy,	450.00
1 oil wagon,	40.00
Tools, etc.,	100.00
	$6065.00

The first piece of work done was the digging of a ditch 6,630 ft. long and 26 in. wide. Cutters or digger reamers 24 in. wide were used on the excavating wheel. The ditch was made for a line of 18-in. hard-burned bell tile, with a diameter, outside of bell, of $25\frac{1}{2}$ in. The steel curbing furnished with the machine could not be used on account of these extreme conditions, and the ditch caved badly. About 100 per cent. more earth was removed from the trench than is ordinarily necessary. Near the upper end of the ditch was a pond 400 ft. wide. The ditch through this pond was cut by a capstan plow.

The time required for the excavation of this ditch was 21 working days.

The depth of the ditch varied from 2 ft. at the outlet to 7 ft. at the upper end, the average cut being about $4\frac{3}{4}$ ft.

The following crew was used on the work:

1 foreman	1 level man
1 engineer	2 laborers
1 machine operator	1 cook
1 tile layer	1 team

Board, washing, etc. for the camp cost $100 per month. Incidental expenses, repairs, etc. cost $80 per month. In the operation of the machine for the digging of this ditch, 368.5 gal. of gasoline were used. To this should be added 15 per cent. which was wasted.

The second job was the excavation of a ditch 4,600 ft. long and 17 in. wide for 12-in. tile. The minimum cut was 3 ft. at the head of the ditch and the maximum 7 ft. near the center. The average cut was 5 ft.

The crew used and the general expenses were the same as in the first case. The excavation of the entire ditch required 5 days. The soil did not cave and the steel curbing was not used. Fifty-five gallons of gasoline were consumed in this operation.

113. Austin Tile Ditcher.—This excavator is especially built for the digging of tile trenches by the F. C. Austin Drainage Excavator

Co. of Chicago, Ill. The machine consists of a steel-frame platform supported upon two trucks and carrying the machinery and digging appliance.

The platform is a steel framework made up of steel channels for the sides and braced with steel angles and plates. The two trucks which support the machine are placed under the front and rear ends of the platform. The front truck is composed of two steel wheels with flanged tires to prevent slipping. The rear truck is provided either with large wide-tired steel wheels or roller platform traction. The latter is generally used as it better distributes the weight of the machinery and excavating chain over soft ground. Each tractor has a bearing area of 10 sq. ft. and will support an excavator over ground that will carry the weight of a man.

The power equipment is placed upon the forward end of the platform, over the forward truck. This generally consists of a gasoline engine, although a steam engine and boiler are furnished if desired. The gasoline engine is of the vertical water-cooled type and provided with two, three, or four cylinders 7 in. by 9 in. and generating from 10 to 50 h.p. These engines are very strongly built and have the following features: the valves are forged from chrome steel with large egress and ingress and operated by rocker arms from the engine cam-shaft, the cams are made from tempered tool steel, the crank-shaft is made of forged high-carbon steel, a Schebler carbureter and force feed oiling system. The fuel consumption of one of these engines is about one-tenth of a gallon of gasoline per horse-power per hour.

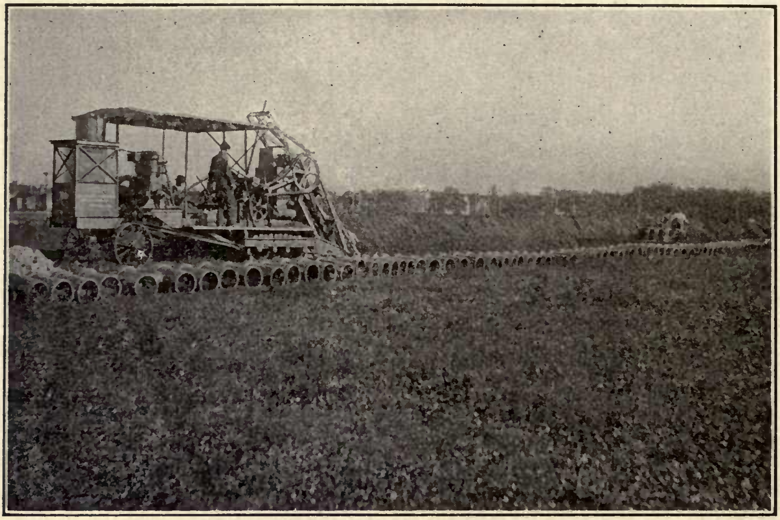
In front of the engine is placed the gasoline-supply and water-supply tanks. This arrangement is clearly shown in Fig. 131.

Over the rear truck, on the platform of the excavator, is placed the operating machinery. This consists of a typical friction-drum engine belt connected to the gasoline engine. A set of gears are used to reduce the speed and a heavy sprocket chain transmits the power to the excavating chain and the belt conveyor.

The rear end of the platform supports a steel box, from the upper and outer corner of which is suspended the steel frame, which carries the excavating chain. The frame is pivoted near its upper end on the axle of the driving sprocket and can be raised and lowered by means of a threaded rod attached to the upper end of the frame and the engine below. Note this detail in Fig. 131.

The excavating chain consists of two link chains and a series of from 9 to 12 buckets. These chains are spaced a distance apart,

depending on the width of trench to be excavated, and pass continuously over sprocket wheels at the upper and low ends of the frame. The links are connected by steel pins and are provided with an outer collar of manganese steel. A broken link can be readily and easily removed and replaced with a new one. The buckets are of the open and scoop type and are provided with tool steel lips or cutting edges. For digging hard soil, manganese steel



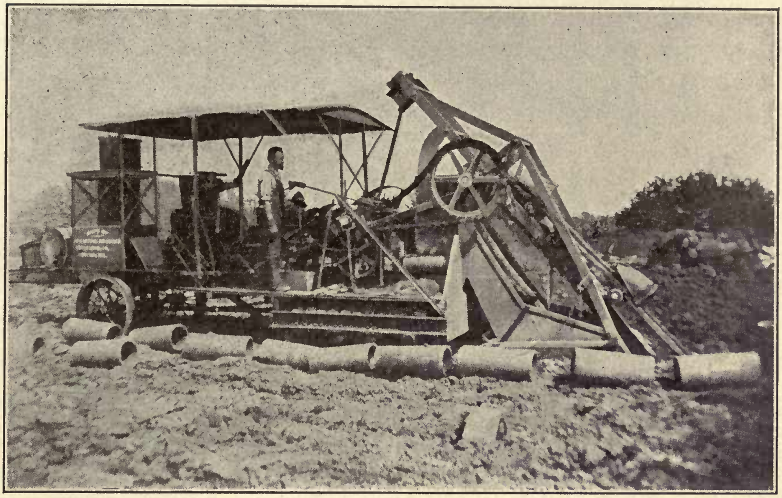
Austin Tile Ditcher.
Figure 131.

reams are attached to the buckets. The chain is supported at intermediate points on smooth steel rollers and revolves continuously. Each bucket in its downward path comes into contact with the bottom of the trench and on its upward path removes a slice of earth, which falls out onto a moving belt conveyor, when the bucket turns over and starts again on its downward path. A fixed scraper is placed so that it automatically cleans out each bucket as it starts to revolve about the upper wheel. This scraper is especially useful when sticky or gumbo soil is being excavated. Fig. 132 is a detail line drawing of the Farm Tile Machine, Size No. 0000. This drawing clearly shows the construction and principles of operation of the excavating chain.

The excavator moves ahead under its own power by means of a gear and chain drive connecting the engine with the axle of the front truck. The average traction speed, when not digging is about

1 mile per hour. When digging the speed varies with the width and depth of the trench and the size of the excavator, the smaller machines moving about 9 ft. per minute and the larger ones about 6 ft. per minute. One man is generally all that is required to operate one of these excavators. In many cases it has been found advantageous to have a boy as a general helper to the operator.

The table on page 296 gives detailed information concerning the trench excavators and their capacities.



Austin Farm Tile Machine.
Figure 132.

114. Résumé.—The tile trench excavator has become a thoroughly practical and economical machine for the excavation of drainage tile trenches. In the loam and clay soils of the average low wet land requiring drainage, this type of excavator, equipped with caterpillar traction, works very efficiently. Where obstructions such as large stone, roots, etc., abound, a large amount of extra hand labor is required.

The tile box or templet, which follows the machine and automatically lays the tile in the bottom of the trench, is a useful device. However, it requires careful adjustment and attention on the part of the operator to secure good results. As a general thing hand-laid tile is more accurate as to alignment and fitting of joints than when laid by machine.

TABLE XXIX

GENERAL DATA FOR DITCHING MACHINE

Size No.	Horse-power		Maximum depth	Width of Cut[1]	Max. digging speed per min.	Traction speed per hour	Delivering dirt on either side	Width of machine on cars[2]	Height of machine over all[2]	Approximate gross weight[2]
	Steam	Gasoline								
0000	....	12	4′ 6″	12″, 15″	12′	$1\frac{1}{2}$ miles	One side	....	....	8,000
000	....	18	6′ 0″	12″, 15″, 18″	10″	$1\frac{1}{2}$ miles	One side	8′ 0″	10′ 0″	18,000
00 Spec.	18	24	8′ 0″	15″, 18″, 24″	9″	$1\frac{1}{2}$ miles	Either side	9′ 0″	11′ 0″	22,600
00	....	36	9′ 6″	15″, 18″, 24″	9″	$1\frac{1}{2}$ miles	Either side	9′ 0″	11′ 0″	24,000
0	18	36	10′ 0″	18″, 24″, 30″, 36″	10″	$1\frac{1}{2}$ miles	Either side	10′ 0″	12′ 0″	40,000
1	35	....	15′ 0″	24″, 30″, 36″	6″	$1\frac{1}{4}$ miles	Either side	10′ 0″	14′ 0″	48,000
1	....	50	15′ 0″	24″, 30″, 36″	6″	$1\frac{1}{4}$ miles	Either side	10′ 0″	14′ 0″	47,000

[1] The digging cuts are the widths of the buckets only. Buckets should never be used without side cutters except in very soft soil. Side cutters will increase the width of cut from $1\frac{1}{2}$ to 4 in.

[2] Figures on width, height and weight are approximate. Different equipments vary these figures somewhat.

The author would suggest that these machines be provided with a longitudinal carrier or conveyor, which would receive the excavated material from the buckets and carry it back over the trench and dump it over the laid tile. Thus the excavating and back-filling would be carried on simultaneously and at a greatly reduced cost. It would be necessary to carry the material back far enough to leave room between the back-filling and the excavator for the tile layer.

To arrive at an approximate estimate of the capacity and cost of operation, let it be assumed that a trench machine of the 14½-in. by 4½-ft. size is to be used for the excavating of tile trenches on fairly level land. The soil will be loam and clay, with gumbo in spots. The working conditions be taken as those generally met with.

Labor:

	Per day	
1 operator @ $125 per month,	$2.50	
1 fireman,	2.00	
1 helper,	2.00	
Total labor cost,		$6.50

Fuel and Supplies:

10 gal. of gasoline @ $0.16,	$1.60	
Oil, waste, etc.,	0.30	
Total fuel and supply cost,		$1.90

Miscellaneous:

Interest @ 6 per cent. (based on investment of $5,200)	$2.00	
Depreciation, 150 working days a year for eight-year life,	4.50	
Repairs and maintenance,	1.50	
Total miscellaneous,		$8.00
Total operating cost per day,		$16.40

Average progress per day,	1,300 ft.
Average daily excavation,	260 cu. yd.
Average cost of excavation,	$0.013 per foot. $0.063 per cubic yard.

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CHAPTER IX

LEVEE BUILDERS

118. Field of Work.—In certain sections of the country, it is necessary to build levees or dikes along the rivers and smaller streams to prevent their periodic overflow. This is especially true of the streams of the central West; the Mississippi, the Missouri, and their tributaries. These streams, particularly in their lower reaches, pass through broad level valleys and are very tortuous. During the spring and early summer floods, these streams inundate the neighboring lowlands and are often very destructive. Hence, measures must be devised to prevent these inundations. One method consists in straightening and enlarging the channels; another, by building earthen embankments or dikes. Sometimes the two methods are combined in one project. This chapter will deal solely with the excavating machinery used in the construction of levees.

Various kinds of earth excavating and moving machinery have been used in the construction of levees. Twenty-five or thirty years ago this class of earthwork was done principally with wheelbarrows, teams, and scrapers. In recent years, however, except in the case of small work, the various types of dredges and specially constructed machinery have almost universally replaced the cruder and slower methods. In the following paragraphs, the various kinds of machines for levee building will be discussed. The levee builder will be described, but the other machines, which have been described in previous chapters, will be only briefly referred to in connection with their adaptability to this particular class of work.

119. Scrapers.—Scrapers are very efficient machines in the building of levees, when the work is on too small a scale for the installation of larger machinery. Both Fresno and wheel scrapers have been used.

A great deal of the levee construction of the lower Mississippi River has been made with wheel scrapers, and this method was found preferable to the use of the wheelbarrow. Earth put up in a bank with the use of wheelbarrows is at first comparatively loose, porous and subject to considerable erosion. Engineers generally allow at least 20 per cent. shrinkage for wheelbarrow work. However, levees

made with the scrapers are fairly firm and hard and readily shed water. About 10 per cent. shrinkage is allowed for scraper work.

120. Fresno Scrapers in Arizona.—The construction of the levee below the Colorado River break, in 1907, was made with four-horse Fresno scrapers. Muck ditches were constructed with 6- to 10-ft. bases and with $2\frac{1}{2}$ to 1 slopes, and then levees with 10-ft. top width and 3 to 1 slopes were built. The material which was an adobe or dark clay and loam, was taken from the borrow pits on the land side. These pits were made with a 40-ft. embankment berm, a depth of 4 ft. on the inside and a slope of 1 in 50 to the outside. At intervals of 400 to 500 ft. were left checks $17\frac{1}{2}$ ft. wide, across the pits. About 150 Fresno scrapers and 600 head of stock were employed continuously on this work. During the month of February, 1907, 270,000 cu. yd. were moved and an average of 7,000 cu. yd. were moved per day.

121. Use of Dump Cars in Massachusetts.—A tidal dike was built, during the latter part of 1908 and 1909, at Wellfleet, on Cape Cod, Massachusetts. This dike was a sand embankment, having a length of about 900 ft., top width of 22 ft. and side slopes of $1\frac{1}{2}$ to 1. The maximum bottom width was 68 ft. The material was borrowed from pits in hills at each end of the dike. A 20-in. gage track was laid from either end of the dike on an incline, so that the dump cars would run out of the borrow pits and on to the dike by gravity. The empty cars were pulled back by means of a cable and hoisting engine. Automatic side dump cars of 3 cu. yd. capacity were used. The maximum haul was 450 ft. and the labor cost was 8 cents per cubic yard.

NOTE.—The reader is referred to Paragraph 2b, Chapter I, for an account of levee construction with Frenso scrapers.

122. Floating Dipper Dredge.—The floating dipper dredge has been successfully used in the construction of levees where the latter are small but it is not a practicable excavator where the levees are large. The dipper dredge must excavate all the borrowed material in front of itself and this means the excavation of a deeper pit than is advisable. This pit would generally be too near the toe of the levee for safety. The dipper dredge has a comparatively short boom and dipper handle and where the cross-section of the levee has over 1,000 cu. yd. per 100 ft. in length, the use of this type of dredge would be impracticable and inefficient.

123. Clam-shell Dredge in California.—Where levees are constructed along large rivers or artificial channels, it is often advisable to use some type of floating dredges. The disadvantages of the dipper dredge have been overcome by the use of a long boom and a clam-

shell bucket. Such a dredge has been used in the reclamation of the delta lands at the junction of the Sacramento and San Joaquin Rivers with San Francisco Bay.

123a. Description of Dredge.—This dredge had a hull whose length was 140 ft., width 50 ft. and depth 10 ft. It was made with two longitudinal and two cross bulkheads, extending from keels to deck. The hull was built of 12-in. square timbers. There were two side and one rear stationary spuds and one fleeting spud. All the spuds were built of single timbers, each 30 in. square and 70 ft. long. The boom was made up of 24-in. square timbers spliced in the center and forming a structure 150 ft. long. The bucket had a spread of 14 ft. and was capable of lifting 14 cu. yd. of excavated material, weighing 25 tons, at one time.

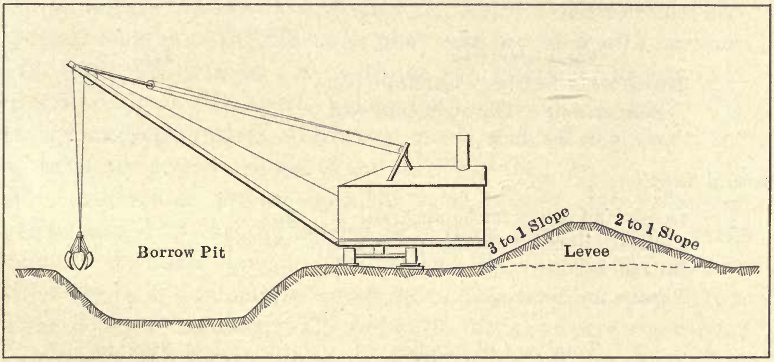


Diagram showing the Use of a Traction Dredge in Levee Construction.
Figure 133.

Power was furnished by a double-cylinder, compound, high-pressure engine of about 500 h.p. The engine was equipped with two 14-in. high-pressure cylinders working into one 41-in. low-pressure cylinder. Steam was furnished by boilers of the Scotch Marine type, having lengths of $13\frac{1}{2}$ ft. and heights of 7 ft. Crude petroleum oil was used for fuel.

123b. Operation of Dredge.—The soil was sand and clay and was easily and efficiently excavated with this type of dredge. When working uniformly, the bucket made a round trip in about one minute. The work was carried on in two 11-hour shifts for each working day and the average excavation was 8,000 cu. yd. The maximum excavation made in a day was about 10,500 cu. yd.

124. Dry-land Dredge in Louisiana.—When the banks of a stream

which is to be diked are of dry and firm soil, a dry-land excavator is used to good advantage. During recent years a number of these excavators, mounted on skids and rollers and equipped with clam-shell or orange-peel buckets, have been operating in Louisiana. The diagram in Fig. 133 will show the method of operation of a traction dredge.

124a. Operation of Dredge.[1]—The following table gives the cost of operation of a traction dredge, equipped with a $2\frac{1}{2}$ cu. yd. orange-peel bucket. These figures are for a typical piece of levee construction in alluvial soil and where clearing is not required.

Labor:

1 engineer @ $120 per month,	$120.00	
1 fireman @ $50 per month,	50.00	
1 track foreman @ $2 per day,	52.00	
4 trackmen @ $1.75 per day each,	182.00	
1 pumpman,	39.00	
Total labor cost,		$443.00
The above is the labor schedule for one 11-hour shift. The night shift cost would be the same:		$443.00

General Supplies:

1 team and driver for hauling coal,	$91.00	
1,040 barrels of Pittsburgh coal @ $0.37,	384.80	
Oil and waste,	10.40	
Repairs and breakage,	78.00	
Total cost of supplies,		$564.20

Total operating expenses for 1 month,	$1,450.20
Average amount of excavation for 1 month,	38,000 cu. yd.
Average cost of excavation per cubic yard,	$0.038

125. Hydraulic and Ladder Dredges.—Hydraulic and ladder dredges have not been used with much success in levee building, except under peculiarly favorable conditions. The material, which these types of dredges excavate, is in such a fluid condition that it will not remain in place in the form of an embankment. The only method that can be used to hold this fluid material in place is first to build two parallel ridges of dry earth or other convenient material, as the toes of the slopes, and then fill in between with the wet material up to the top of the ridges. After the wet filling dries out and solidifies, two more ridges can be built and filled in. This method is continued until the levee is carried to the proper elevation and completed. This process

[1] Abstracted from Circular 74, U. S. Dept. of Agriculture.

is satisfactory in the result, but slow and expensive. When it is necessary to construct levees on wet land and where the excavated material has to be transported a considerable distance, the hydraulic dredge is very useful and efficient.

126. Hydraulic Dredge at Cairo, Ill.[1]—The low areas of land in the city of Cairo, Illinois, have been filled in recently by hydraulic dredging from the Mississippi River. At first, the levees, to contain the fluid-dredge material, were constructed by means of slip scrapers, but later on, a novel scheme was adopted.

The method adopted was based on the fact that the material moving in the discharge pipe moves in strata with the gravel and heavy sand at the bottom, the lighter sand above and the water in the upper section of the pipe. The velocity of the material has been found to be inversely proportional to its density. This motion is not uniform in the pipe, but goes on like wave action with a series of crests and hollows.

Several lengths of the discharge pipe were provided with openings on the lower side, 3 in. by 4 in., with the 4-in. dimension longitudinal, and spaced about 3 ft. apart. These openings could be regulated in size or closed by shutters, which were made of No. 8 sheet steel and worked in cast grooves bolted to the outside of the pipe.

The shutters of several openings were opened, the excavated material issued in the consistency of a thick mortar, which would assume in the bank about a 1 to 1 slope. By opening the shutters farther the escaping material could be made more fluid, and flatten out the slopes of the levee. The end of the discharge pipe was carried to a considerable distance from the levee, so that the escaping fluid material and water would not affect the work.

127. Austin Levee Builder.—The Austin Levee Builder is a templet excavator, built on the same general principles as those described in Chapter VI, Section B. These excavators can be adapted to levee construction by making a few simple modifications.

The levee builder consists of a moving platform, which supports an excavator frame at one end and a levee runway at the other end.

The platform is generally built of timber and has a length of 22 ft. and a width of 20 ft. It carries the power equipment, which is generally housed in. Fig. 134 shows one of the machines at work.

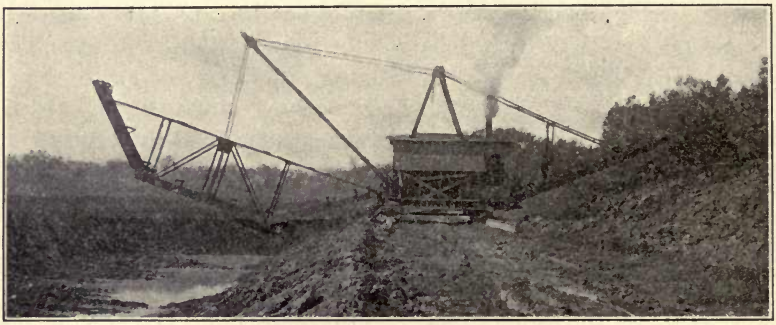
The platform moves on a track made up of 12-in. by 12-in. timbers, 200 ft. in length. On the tops of these are spiked T-rails which take the flanged wheels of the platform trucks. For soft ground, roller platform traction is used.

[1] Abstracted from Engineering-Contracting, Feb. 16, 1910.

The power equipment consists of a steam-boiler and engine. The boiler is a 50-h.p. fire-box locomotive type weighing 10,500 lb. The engine is a 40-h.p. reversible, double-cylinder, double-friction drum, hoisting engine, provided with steel gearing. The engine weighs about 12,000 lb. The makers will furnish a gasoline engine instead of the regular steam equipment if desired.

A four-legged A-frame, made up of structural steel members is supported on the platform. From the top of this frame, cables pass over steel sheaves to the outer ends of the excavator frame and the levee runway. These cables are connected to the drums of the hoisting engine and thus control the raising and lowering of these two frames.

On the outer or borrow pit end of the platform is hinged a steel frame or guideway, which has the general shape of a ditch cross-section,



Austin Levee Builder.
Figure 134.

and can be raised and lowered by the operator by means of steel wire cables passing over a sheave at the outer end of the frame, thence to a sheave at the top of the A-frame and thence to the engine. This frame forms a track over which a bucket passes. The bucket commences at the farther outside bearing of the runway and is drawn by a wire cable attached to the engine drum toward the machine, passing along the guideway and then across the berm and up the levee runway and dumped. Thus the bucket in its path moves over a continuous guideway or steel track which extends from the outer point of the borrow pit, in front of the platform and to the center of the levee. The bucket after dumping is pulled back along its track to the outer point of the cutting frame, where it commences the excavation of another slice of earth. The frame is gradually lowered as the bucket excavates, until

the bottom of the frame is horizontal. Then the frame is raised and the whole machine moves ahead about 3 ft. and another section of the pit is excavated.

The bucket used is made of steel plate with heavy manganese steel cutting edge. Its length is 48 in., depth 36 in. and width 43 in. Buckets having capacities of from $1\frac{1}{3}$ to $2\frac{1}{2}$ cu. yd. each, can be used on this machine. The approximate weight of a 2 cu. yd. bucket is 3,000 lb.

This levee builder is made to excavate borrow pits with $1\frac{1}{2}$ to 1 or with 1 to 1 side slopes. With $1\frac{1}{2}$ to 1 side slopes, the machine can excavate a pit having a maximum depth of 20 ft. and bottom width of 20 ft., and a minimum bottom width of 5 ft. With 1 to 1 side slopes, the maximum depth would be 30 ft. and corresponding maximum bottom width of 30 ft., and a minimum bottom width of 6 ft. The width of berm varies from 20 ft. to 40 ft. depending on the amount of material to be placed in the levee and local conditions.

Under favorable conditions this machine will excavate and dump about 1,000 cu. yd. of earth per 10-hour day. The labor required is an operator, a fireman, a track gang composed of two men and a team of horses and a man and team for hauling supplies, fuel, etc. When roller platform traction is used the track gang is not necessary, except when the soil is very soft and one or two extra laborers are required for planking. About 2 tons of coal are used in a 10-hour shift. The operating cost for a 10-hour day would vary from \$25 to \$30, when the soil conditions were favorable.

The F. C. Austin Drainage Excavator Co. have also designed a multiple bucket excavator for levee work. This machine consists of two moving platforms, each carrying its operating machine and excavator. The excavator consists of a triangular-shaped steel-truss frame supported at its inner end on the platform and also near its center by a cable from a crane, extending from the platform out over the excavator frame. The latter carries a continuous chain equipped with steel buckets, which cut out the soil as the frame is gradually lowered. At the platform end of the bucket chain, the buckets dump their loads as they turn over. The excavated material is dropped on a moving belt conveyor, which carries the material to the levee. The excavator frame and belt conveyor can be raised and lowered by the operator.

This excavator can be duplicated on the other side and a double levee constructed as is often necessary in straightening out and enlarging a natural watercourse. Each machine is designed to dig

a pit having a bottom width of 40 ft., depth of 20 ft., and side slope of 2 to 1. The berm would vary from 40 ft. to 60 ft.

128. Résumé.—In the choice of an excavator for levee construction, the principal considerations are capacity, ability to quickly transport material over wide spaces and provision for removing water before material is deposited in spoil bank.

In the early days of levee building, the wheelbarrow and the scraper were used entirely. Recently, the machine excavator has to a great extent supplanted the earlier types and with very satisfactory results.

The floating dipper dredge is useful in the building of small levees along the smaller streams. However, when the levee contains over 1,000 cu. yd. per station of 100 ft., the boom of the dipper dredge is not long enough to properly excavate the borrow pit and place the levee.

For large levees, the dry-land excavator is the best suited for average conditions. The clam-shell bucket traction excavator with a long boom is generally the most efficient type. These machines are built with booms up to 125 ft. in length and with a capacity of 3,000 cu. yd. per 11-hour shift.

Recently, a templet machine has come into use and under favorable conditions, operates very satisfactorily. It is not adapted to use in hard soil or where there are many large stones, stumps, or other obstructions. It digs a borrow pit of smooth and uniform cross-section and deposits the material by means of an adjustable belt conveyor, at any desired distance from the pit. The work which this machine does is nearly mechanically perfect, and has a much more finished appearance than that done with a dredge.

The author prefers a levee made with scrapers on account of the constant compacting given the embankment during construction, by the moving over it of the teams. Although the material falls from a machine excavator with considerable force, yet the resulting consolidation in the bank is usually "spotty" and uneven.

The capacity of an excavator in levee construction depends on local conditions, size of excavator, operation, supervision, etc. A machine excavator equipped with a $1\frac{1}{2}$-cu. yd. bucket or dipper, under average working conditions should excavate and place about 1,000 cu. yd. during a 10-hour day at an average operating cost of about 5 cents. The average cost of construction with scrapers would be about 8 cents.

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CHAPTER X

THE COMPARATIVE USE OF EXCAVATING MACHINERY

132. **General Considerations.**—It is clearly impossible to lay down any rules or state any formulæ by means of which an excavator could be arbitrarily selected for any proposed work. There are always so many variable conditions and unknown and unforeseen factors to consider, that it is to a great extent a matter of *judgment.* This essential but rare quality is born in some people, but by most of us must be acquired by experience.

One of the primary considerations in the choice of an excavator for any particular piece of work is the size of the job or the amount of excavation to be made. Unless the work is of sufficient magnitude, it would not pay to use a dredge which must be shipped knocked down or in a dismantled condition, transported to the site of the proposed work, and erected. All this is expensive and requires some weeks and sometimes several months. This outlay must be added to the operating expenses in order to determine the total cost of the work. Hence, it is not generally economical to use a dredge on a job where not more than 50,000 cu. yd. of excavation can be handled with one set-up of the machine. A small work, such as an isolated ditch or levee, is often a difficult thing to construct, because the average contractor does not care to take the trouble to ship an excavator to the site of the work for the possible small profit. The author recalls several cases where it was necessary, after long delays, to interest and instruct local parties in the use of simple types of excavators, in order to get ditches built. There is at present (1913), a great field throughout the South and West for excavators adapted for small ditches. A machine of the wheel excavator type, as described in Section C, Chapter VI, is probably the best for such work.

A contractor generally uses the machinery which he happens to have on hand, sometimes without regard to its adaptability for the proposed work. To contractors with small capital this is perhaps an economic necessity. But, as a rule, it is for the interest of the contractor, the client and all concerned, that the most suitable

and efficient machine shall be used, and used intelligently on every piece of work. To that end, the engineer should recommend the type of excavator to be employed and the client should see that his contract with the contractor contains a clause requiring that *proper and efficient machinery shall be used at all times on all parts of the work.*

The following tables of the comparative costs of the various types of excavators are given to supply in a purely relative manner this information on a few representative jobs, where such information has been accurately compiled.

133. **Massena Canal, New York.**—A large hydraulic power canal in St. Lawrence County, N. Y., was constructed from 1897 to 1901, to divert water from the St. Lawrence River for power purposes. The canal has a length of about 3 miles, top width of 225 ft. and average depth of 25 ft. The material excavated was mostly sand, clay and gravel, but considerable indurated clay and boulders were removed.

HYDRAULIC DREDGE NO. I

This dredge had a southern pine hull, 65 ft. long, 30 ft. wide, and 6 ft. deep. The A-frame was of 12×12.-in. timbers 45 ft. high and there were two spuds of 9×16 in. and 40 ft. long. The wrought-iron suction and discharge pipes were 1 ft. in diameter and the suction pipe was equipped with a rotary cutter to loosen the material. Steam was supplied by a 125-h.p. boiler to a Lidgerwood, compound, condensing engine of 125 h.p. The excavated material was lifted to a height of 30 ft. above the water level, excavated to a depth of 22 ft. below the water surface and discharged 1,200 ft. The average discharge contained 25 per cent. of solid material, ranging from 7 to 30 per cent. This dredge successfully excavated sand, clay and gravel but could not remove the indurated clay. The total working time was three seasons of about eight months each, six days per week and two shifts of 11 hours each per day. Each shift contained the following labor:

1 captain
1 engineer
1 fireman
1 oiler
1 deckhand foreman
3 laborers @ 15 cents
The total labor cost for an 11-hour shift was $17.95.

The daily operating cost is as follows:

Labor and supervision,	\$35.90
9 tons coal @ \$3,	27.00
Oil, waste, etc.,	5.00
Interest, repairs and renewals,[1]	26.80
Care during winter, \$209,	1.00
Total for 22-hour day,	\$95.70
Average daily output,	1,125 cu. yd.
Cost of excavation per cubic yard,	8.5 cents.

HYDRAULIC DREDGE NO. II

This dredge was provided with 18-in. diameter suction and discharge pipes and was similar to Dredge No. I, except that it was larger in every way. The material and distance to which it was moved were the same. A spudman was required extra for this larger dredge, making the total labor cost, for an 11-hour shift, \$20.95. The same rates of interest and depreciation were assumed but based on an initial cost of \$60,000.

The daily operating cost is as follows:

Labor and supervision,	\$41.90
18 tons coal @ \$3,	54.00
Oil, waste, etc.,	8.00
Interest, repairs and renewals,	40.19
Care during winter,	1.00
Total for 22-hour day,	\$145.09
Average daily output,	1,544 cu. yd.
Cost of excavation per cubic yard,	9.4 cents.

DIPPER DREDGE

This dredge had a hull 85 ft. long, 28 ft. wide and 10 ft. deep. Three timber spuds, 20 in. square were used. The dipper arm was 28 ft. long of timber sheathed with steel and carrying a dipper of 2 ½ cu. yd. capacity. The cutting edge of the dipper was provided with three steel teeth, about 6×5 in. The excavated material was deposited in two scows, each having a dropping pocket with a capacity of 140 cu. yd. A tug towed the scows into the St. Lawrence River,

[1] The annual depreciation and repairs were assumed as 10 per cent. on the initial cost of \$40,000 or \$4,000. Interest on the investment was taken at 4 per cent. or \$1,600. This makes a total overhead charge of \$5,600, which at 209 working days per year, gives a daily expense of \$26.80.

an average distance of about 5,500 ft. The daily wages of the crew of dredge, tug and scows, the cost of coal, supplies, etc., amounted to $30.56 for 10 hours.

The daily operating cost is as follows:

Labor, supervision, coal and supplies,	$30.56
Interest repairs and renewals,[1]	28.80
Care during winter,	1.00
Total for 10-hour day,	$60.36
Average daily output,	754 cu. yd.
Cost of excavation per cubic yard,	8.0 cents.

Two other dredges worked one season. The larger dredge had a 6-cu. yd. dipper, while the smaller one had a 1 ½-cu. yd. dipper. The cost of operation was practically the same as for the 2 ½-cu. yd. dredge.

The dipper dredges were successful in the handling of the indurated clay and boulders. The former had to be blasted when dry in order that the dredge could excavate it.

134. The Colbert Shoals Canal, Alabama.[2]—The Colbert Shoals Canal was constructed several years ago (1905–06–07), along the south bank of the Tennessee River to overcome the obstructions to navigation offered by the Colbert and Bee Tree Shoals in the river. The lower end of the canal is near Riverton, Alabama. The section of the canal to be considered lies through the bottom-lands of the river valley. These lands were of an alluvial formation and were low away from the river along the hills. Part of the canal was located in this lowland and this necessitated the wasting of all the material on the river side of the canal.

The canal (section under consideration) has a length of 5.3 miles, a bottom width of 112 ft. and side slopes of 2 to 1. Berms of 15 ft. width were left on both sides of the canal and the berm on the river side was brought to a height of 95 ft. above low water in the canal.

Several kinds of excavators were used in this work and were used successively as occasion demanded for the excavation of different classes of material. The wheel scrapers, elevating graders and steam shovel were used to remove the upper and loose soil, while the drag-line excavators were applied to the lower and harder soil. The

[1] The annual depreciation and repairs were assumed as 10 per cent. on the initial cost of dredge, tug and two scows, of $43,000 or $4,300. Interest on the investment was taken at 4 per cent. or $1,720. This makes a total overhead charge of $6,020, which at 212 working days per year, gives a daily expense of $28.80.

[2] Abstracted from Professional Memoirs, U. S. Engineers, Oct.–Dec. 1911.

latter were also found to be more efficient in excavating in pits containing 2 to 3 ft. of water, and heavy rains did not interfere with their operation. This was found to be the only type of excavator which could work continuously through the day with two or three shifts.

Following is a detailed description of the various types of excavators used.

Wheel Scrapers and Elevating Graders.—The wheel scrapers used were standard two-wheel scrapers with two-horse teams. The elevating graders used were the "Standard Western Elevating Graders," equipped with 21-ft. elevators and using extra heavy plows.

The scrapers were used to assist the elevating graders in excavating and filling runways, stripping the surface of sod and cornstalks and in preparing roadways for the traction engines, which hauled the elevating graders. The latter were served by eight four-horse dump wagons for each machine. The only portions of the canal completed by the graders were the two sections from Stations 10 to 20 and from Stations 145 to 163. The graders were found impracticable in excavating sticky "gumbo" soil, and hard pan. On the section from Stations 222 to 290, the graders with the assistance of the scrapers made an excavation 110 to 120 ft. in width and from 8 to 10 ft. in depth. This left a berm of about 30 ft. in width on each side for the drag-line excavators to work from in completing the excavation.

Drag-line Bucket Excavators.—Two Armstrong excavators equipped with 2-cu. yd. Page buckets were used. These machines were of the standard revolving traction type and were equipped with 81-ft. booms and double-drum hoisting engines with 10×12-in. cylinders. A third drag-line excavator known as the McMyler machine, was used in coördination with the two Armstrong excavators. This excavator was equipped with a 1 ½-cu. yd. bucket.

These machines moved along the berms left by the scrapers and elevating graders and completed the excavation in the following manner. One Armstrong machine operated in front taking out the section from the center of the ditch to the foot of the side slope, the McMyler machine followed and trimmed the slope and the other Armstrong excavator followed on the other berm and removed the remainder of the material.

Steam Shovel.—The steam-shovel outfit consisted of a 65-ton Marion shovel, one 25-ton and one 20-ton dinkey locomotive, light "Oliver" 12-yd. side-dump cars, about 1¾ miles of standard-gage track, a tank, pipe line and pump.

TABLE XXX

COST OF CANAL EXCAVATION WITH VARIOUS TYPES OF EXCAVATORS

Stations	Wheel scrapers		Graders		Excavators		Steam shovel		Total
	Quantity	Cost per cu. yd.	Quantity	Cost per cu. yd.	Quantity	Cost per cu. yd.	Quantity	Cost per cu. yd.	Excavation, cu. yd.
10–135	90,000	$0.18	267,202	$0.14	400,000	$0.12	....	....	757,202
135–163	52,000	0.22	221,674	0.17	....	0.30	....	....	273,674
163–196	25,335	0.24	255,150	0.20	55,000	0.30	....	....	335,485
196–222	....	....	....	....	42,240	0.22	187,559	$0.28	229,799
222–260	30,073	0.20	102,000	0.15	200,000	0.11	....	....	332,073
260–290	10,000	0.23	71,112	0.16	192,027	0.09	....	....	273,139
Total	207,408	....	917,138	....	889,267	....	187,559	....	2,201,372

The steam-shovel outfit operated between Stations 196 and 222 in the removal of the hillside and the dry material from the top of the cut. It was found that the shovel was too large for economical operation with the small-train equipment. The lower section of the trench ran through such soft material in places as to make the use of the shovel impracticable. About 42,000 cu. yd. of this section were completed by the drag-line excavators.

The table on page 313 gives the quantities and unit costs on this work.

The following table shows the comparative daily labor costs of operation for the various excavators:

Drag-bucket Excavators

3 engineers @ $260 per month,	$8.66
3 firemen @ $2 per day,	6.00
3 laborers @ $1.50 per day,	4.50
1 master mechanic @ $125 per month,	4.16
1 pumpman @ $1.50 per day,	1.50
1 blacksmith @ $3 per day,	3.00
1 foreman @ $75 per month,	2.50
1 coal wagon driver @ $2. per day,	2.00
Total for 3 excavators,	$32.32
Cost for each excavator,	$10.77

Elevating Graders

2 engineers @ $80 ($160), per month,	$5.33
2 firemen @ $1.75 per day,	3.50
16 teams (four-horse) @ $2.50 per day,	40.00
1 water wagon with driver, $2 per day,	2.00
1 pumpman @ $1.50 per day,	1.50
1 blacksmith @ $3 per day,	3.00
1 helper @ $1.50 per day,	1.50
1 foreman @ $75 per month,	2.50
Total cost for two graders,	$59.33
Cost for each grader,	$29.66

Wheel Scrapers

15 wheel scrapers @ $2 per day,	$30.00
3 snap teams @ $2.25 per day,	6.75
5 laborers @ $1.75 per day,	8.75
1 blacksmith @ $3 per day,	3.00
1 helper @ $1.50 per day,	1.50
1 foreman @ $75 per month,	2.50
Total cost,	$52.50
Cost for each scraper,	$3.50

STEAM SHOVEL

1 foreman @ $125 per month,	$4.16
1 shovel engineer @ $125 per month,	4.16
1 craneman @ $90 per month,	3.00
1 shovel fireman @ $2.00 per day,	2.00
1 blacksmith @ $3.00 per day,	3.00
1 helper @ $1.50 per day,	1.50
1 pumpman @ $1.50 per day,	1.50
1 coal wagon @ $2. per day,	2.00
2 dinkey engineers @ $2. per day,	4.00
2 fireman @ $1.50 per day,	3.00
2 brakeman @ $1.50 per day,	3.00
16 laborers on dump @ $1.50 per day,	24.00
3 laborers at shovel @ $1.50 per day,	4.50
Total cost,	$59.82

135. **State Drainage Work, Minnesota.**—The following figures are given by Mr. George A. Ralph, State Drainage Engineer of Minnesota for the period from 1886 to 1906:

SLIP SCRAPER WORK

	Cost per c.u. yd.
Not exceeding 6 ft. in depth,	$0.10
Not exceeding 10 ft. in depth,	0.12
Not exceeding 12 ft. in depth,	0.14
New Era grader work,	0.08
Shovel work, 2 to 6 ft. deep,	0.15
Shovel work, 2 to 10 ft. deep,	0.20
Hayknife work, 2 to 4 ft. deep,	0.12
Hand labor in timbered swamps,	$0.15 to 0.20
Good dredge work,	0.08
Dredge work, unfavorable conditions,	$0.10 to 0.14
Capstan plow,	$0.40 to 0.60

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APPENDIX A

GENERAL SPECIFICATIONS FOR A MODERN STEAM SHOVEL FOR RAILWAY CONSTRUCTION

The following is an abstract of the report of a subcommittee of Committee No. 1 on Roadways to the American Railway Engineering and Maintenance of Way Association at its Eighth Annual Convention in Chicago, Illinois, March 19 to 21, 1907.

The Committee made the following recommendations as regards the use of different classes of shovels for different purposes.

(1) In opening up new lines, it is often advisable to have a small light traction shovel to precede the regular work and cast out to the sides material from cuts, so that the loading track grades may be reduced and economically operated.

(2) A standard shovel, such as the Committee will recommend, will be required, and will be available either on new lines or for improvement work.

(3) It frequently occurs that a standard shovel is too heavy for certain soft cuts where it might be advisable to finish with a much lighter class of machine.

(4) Many railroads are fortunate in possessing large ballast pits, in which it would be advisable to use a shovel much larger than the standard.

In any event, and irrespective of the use to which the shovel is assigned, there are three important cardinal points that should be given careful attention in the selection of any and all machines of this class.

These are in their order:

(1) Care in the selection, inspection and acceptance of all material that enters into every part of the machine.

(2) Design for strength.

(3) Design for production.

The Committee makes the following recommendations as to the specifications for a Standard Shovel, which will meet the largest requirements for "General Roadway Construction."

(1) **Steam Shovels.**

(a) Weight, 70 tons.

(b) Capacity of dipper, 2½ yd.

(c) Steam pressure, 120 lb.

(d) Clear height above rail of shovel track at which dipper unloads, 16 ft.

(e) Depth below rail of shovel track to which dipper will dig, 4 ft.

(f) Number of movements of dipper per minute from time of entering bank to time of entering bank, three.

(g) Cable hoist.

(h) Cable swing.

(i) Permanent housing of engineer and fireman and also protection for cranesman.

(j) Capacity of tank, 2,000 gal.

(k) Capacity of coal bunker, 4 tons.

(l) The following list of repair parts should be carried.

1 hoisting engine cable or chain.
1 thrusting engine cable or chain.
1 swinging engine cable or chain.
1 set dipper teeth.
1 dipper latch.
12 cold shuts.
6 cable clamps.
1 U-bolt.
Duplicate of each sheave on machine.
Lot assorted bolts and nuts.
Lot assorted pipes and fittings.
Lot assorted water glasses.

(m) The following list of repair tools should be carried.

1 blacksmith forge with anvil and complete tools.
1 small bench vise.
3 pipe wrenches, assorted sizes.
3 monkey wrenches, assorted sizes.
6 chilson wrenches, assorted sizes.
1 ratchet with assorted twist drills.
6 round files, assorted sizes.
1 hack saw, with twelve blades.
1 set pipe taps and dies.
1 set bolt taps and dies.
6 cold chisels, assorted sizes.
2 machinist's hammers.
2 sledges.
2 switch chains.
2 re-railing frogs.
2 ball-bearing jacks.
1 siphon, complete.
1 axe.
1 hand saw.
1 set triple blocks with rope.
2 lining bars.

1 pinch bar.
6 shovels.
6 picks.
1 coal scoop.
1 flue cleaner.
1 fire hoe.
1 clinker hook.
1 slash bar.
2 hand lanterns.
2 torches.
Assortment of packing.
Assorted oil, in cans.

(n) A spread of jack arms, 18 ft.

(o) Four pitmen.

(p) Balance of opinion is against the construction of the shovel so that it may swing back of the jack arms, so that cars can be loaded in tunnel or rock work where entrance is narrow and cars cannot be pulled beyond shovel.

(2) Shovel track.

(a) Use "T" rails on ties.

(b) Sections should be 6 ft. long.

(c) Strap joint.

(3) Gage of track for dump cars.

(a) Use standard gage.

(4) Style and capacity of disposal cars.

(a) Use 6-yd. dump cars where the cut is under 6 ft. and haul is less than 1 mile.

(b) and (c) Use standard car with permanent sides with swinging hinged doors and cars connected by aprons, where cut is under 6 ft. and haul is from 1 to 6 miles and over.

(d) Use 6-yd. dump car where the cut is over 6 ft. and the haul is less than 1 mile.

(e) and (f) Use same car as described under (b) and (c) where the cut is over 6 ft. and the haul is from 1 to 6 miles and over.

The following recommendations are made concerning the standard flat car.

(1) See that car is strong enough for the purpose.

(2) Note that brake-wheels are in good condition, and in case material is to be plowed off, these must be placed at side of car.

(3) Care should be taken that stake pockets are in good condition and not spaced too far apart. Four feet apart in center of car and closer at ends is considered good practice.

(4) See that the stakes are strong enough to prevent accident or derailment of plow.

(g) Use light cars and light trestles where dirt is dumped from trestle to fill for a haul less than 2 miles.

(5) Operation of unloading plows.

(a) Cable should be handled with an auxiliary engine and drum. The machine should be able to develop a 60-ton pull and weigh about 28

tons. Steam cylinders 12×12. Diameter of drum, 4½ ft., which will permit four wraps of 1½-in. cable to be made.

(b) Upon track with light raise, use center plow, but side plows are more advantageous in making heavy fills.

(c) Use of reversible plow is not satisfactory.

(d) Use a strong plow with trailer. Plow should be not less than 4½ ft. high and 36 ft. in length over all.

(e) Weight of plow should be 7 tons.

(6) Size and length of cable.

Use a 1½-in. diameter cable with a length of 1,200 ft.

(7) Form of spreader or leveler.

(a) Use a two-arm spreader.

(b) Use air pressure for operation.

(c) Use a spread of wings of 20 ft.

(d) Angle of wings should be 45 degrees.

(e) Spreader should deposit material 2 ft. above rail.

(f) Spreader should work 2 ft. below rail.

(8) Construction of embankments with trains on a new location.

(a) A vertical limit of 4 ft. should be used when raising track with material dumped.

(b) Four feet should not be exceeded in the use of a central core put up by teams and widened with shovel material. This method should be used only when material can be cheaply borrowed from the side.

(c) Use a temporary filling trestle for fills over 4 ft. in height.

(d) Other methods would comprise the use of ordinary graders, cableways, power scrapers, traveling cranes, suspended bridges and other types of mechanical appliances. The economical and efficient use of these would depend upon conditions and the amount of material to be handled.

(9) Construction of embankments with trains in present location of track under traffic.

(a) Where sand, gravel or cinders can be used, under ordinary circumstances it might be economical to use this method, where the track is not to be raised to exceed 4 ft. The lifting should be done gradually with no one lift to exceed 6 in.

(b) When track is to be raised to exceed 4 ft. construct a temporary track to one side to carry traffic and jack up main track vertically in place.

(c) When track is to be raised to exceed 6 ft. throw main track to one side and build a trestle.

(d) Other methods would be as follows. Build a new temporary grade outside of the slopes stakes for the new embankment. Widen the embankment to its full width and build it as much higher as it can be made to avoid interference with traffic; then build a new track on this new bank, when the old track can be taken up and bank raised. This last method is to be continued until the final height is attained.

(10) Allowances for shrinkage in new embankments.

Shrinkage should be allowed for both in the width and height of an embankment. The following quotation is made from a letter of Mr. F. J. Slifer, chairman of this Committee, to a member of the Association.

"In reply to yours of June 19th, I would say that there appear to be no

theoretical rules to decide what amount of allowance should be made for settlement of new enbankments. Naturally the question is affected by the character of the foundation under the embankment and the character of the material making the embankment. The ordinary rule is to use 10 per cent. for shrinkage in height up to 25 ft. and 15 per cent. for banks over 25 ft. in height, looks well in a book, but it would appear foolish to follow such a rule by making a 100-ft. embankment 115 ft. high. If you did so, the chances are that you would have to lower the grade before the track could be laid.

"I believe it a good practice to allow 10 per cent. in height with a limit of 5 ft., which I would not exceed unless the foundation is in a swamp.

"It is now conceded that the proper place to provide for shrinkage of embankments is in the width, and here there can be no limit. However, in your case, where you have good material and foundations, with very high banks, I would recommend:

10 per cent. increase in width of banks less than 25 ft. high.
15 per cent. increase in width of banks between 25 and 50 ft. high
20 per cent. increase in width of banks between 50 and 75 ft. high.
25 per cent. increase in width of banks between 75 and 100 ft. high.

"Possibly the latter is too strong, and that there should be a limit to increasing width as well as height. Banks will naturally settle, and you want the material on the shoulders so that the track forces may keep the roadway built up to its full height and width.

(a) Allow 15 per cent. shrinkage for black dirt, trestle filling.

(b) Allow 5 per cent. shrinkage for the use of black dirt in raising a track under traffic.

(c) Allow 10 per cent. shrinkage for clay, trestle filling.

(d) Allow 5 per cent. shrinkage for the use of clay in raising a track under traffic.

(e) Allow 6 per cent. shrinkage for sand, trestle filling.

(f) Allow 5 per cent. shrinkage for the use of sand in raising a track under traffic.

The Committee recommends the use of the three blank forms shown below, to give the results of steam-shovel work, including quantity of material moved and itemized cost of same. These separate forms are as follows:

First.—A daily report for the purpose of competition between different shovel crews through the medium of local advertising the result of each shovel track. Such reports are known to have an excellent effect on the unit cost of the work.

Second.—A daily report for local office use in reporting amount of work done with itemized costs.

Third.—A monthly report for general office use in reporting details for the period's operation.

First

RECORD OF STEAM SHOVEL NO.............

From ....M........191... To..........M........191...
Engineer .... Cranesman ....
Material .... Average haul stations...............
Locomotives No.................... Cars No............ Size................
Total minutes loading... No. Cars........ Minutes per car. .No. dippers...
Seconds per dipper..................Approximate yardage................
Total minutes moving. . . No. moves......... Minutes per move..........
Minutes delay waiting for Cars..... Weather...............................
Other delays (Minutes).......... General conditions......................
Total hours worked........... Hours lost......... Total hours on duty. .
Cause hours lost...

Shovel moved and ready.	Shovel began loading.	Delays waiting for cars.	Finished loading and ready to move.	Time loading.	Cars.	Dippers.	Time moving.	Other delays.		Cause of delay and remarks.
								From	To	
Time.	Time.	Mins.	Time.	Mins.	No.	No.	Mins.	Time.	Time.	Mins.
Total										

....

Inspector.

Second: A Daily Report for local office use in reporting amount of work done with itemized costs.

DAILY STEAM-SHOVEL REPORT

STEAM SHOVEL NO........at....................... ....191..

Face of Bank............................Average Length of Haul.........

DETAILS OF LABOR. CARS LOADED.

S. S. Crew commenced wk...M.

S. S. Crew quit work........M.

Capacity in yds. No. cars Yds per car. Total yards.

Hrs. Rate. Amt. Hart Convert. 34′ 80,000 35.6 side.........

S. S. Engineer.............................. 34′ 80,000 25.3 cent..........

S. S. Fireman..............Rogers....... 34′ 100,000 29.3..............

S. S. Cranesman.............................. 34′ 80,000 29.3..............

S. S. Watchman.............................. 34′ 40,000 ....

S. S. Pitmen...............Haskell &

Car Repairers..............Barker....... 40′ 80,000 36.20.............

Laborers...

Pumpmen.................Ingoldsby..... 42′ 100,000 42.4..............

TOTAL...

.........................Flats............ 80,000 29.3..............

Spotting Crew com'd work.....M............ 60,000 22 ....

Spotting Crew quit work.......M............ 50,000 18.3..............

.... 40,000 14.7..............

.........................Coal............ 60,000 36 ....

Engine No.. 50,000 32.5..............

Engine No.. 40,000 23 ....

Engine No................6 yd. dump cars........... 6 ....

Conductor................5 yd. dump cars.......... 5 ....

Brakemen.................. TOTAL...................................

Engine Watchmen..........Loads left over from previous day..............

.........................Average cost per cubic yard for labor............

.........................Average cost per cubic yard for material..........

TOTAL.................Average cost per cubic yard for superintendence,

Superintendence, etc........ plant, rent, etc............................

GRAND TOTAL.......... TOTAL Average cost per cubic yard.........

SUPPLIES, LOCOMOTIVES, CARS, PUMPS, ETC.

Cts. Pts. Cost. Cts. Pts. Cost.

Valve Oil.........................Coal Loco.........................

Engine Oil........................Waste C. C........................

Car Oil...........................Waste Wool........................

Signal Oil..

Headlight Oil...

Coal Shovel...................... TOTAL.............................

Kind of material handled..

Character of work performed...

Track Conditions..

General Conditions..

Weather...

DELAYS

	Hrs.	Min.	Remarks.
Waiting for cars............			
Moving Shovel............			
Repairing Shovel............			
Repairing Locomotive............			
Other Delays............			
TOTAL DELAYS............			

..................................(Signature).

Third: A Monthly Report for General Office use in reporting details for the period's operation.

MONTHLY STEAM-SHOVEL REPORT

STEAM SHOVEL NO..........AT....................MONTH................
Average Face of Bank................Average Length of Haul...............

General:

Number of Days Worked..
Average Daily Car Output......................................
Average Cubic Yards per Car ....
Total Cubic Yards...
Average Cubic Yards per Day....................................
Actual Time Worked by S. S.....................................
Time Delayed..
Percentage of Delays..
Number and Kind of Cars Used...................................
Number and Kind of Engines.....................................
Kind of Material..
Character of Work Performed....................................
Track Conditions..
General Conditions..
Weather...

Total. Per day. Per yard.

Labor:

Cost Shovel Service...
Cost Train Service..
Cost Car Repairs..
Cost Dumping Cars...
Cost of Superintendence and Plant Rental.......................
TOTAL Cost Labor..

Total cost. Used per day. Cost per day.

Supplies:

Valve Oil...
Engine Oil..
Car Oil...
Signal Oil..
Headlight Oil...
Coal for Shovel...
Coal for Engine...
Waste C. C. and Wool..
TOTAL Supplies..

Per yard. Per day.

Total:

Total Cost Labor..
Total Cost Supplies...
Total Cost S. S. Work...

APPENDIX B

TESTS OF THE MISSISSIPPI RIVER COMMISSION FOR HYDRAULIC DREDGES

The dredges Alpha, Beta, Gamma, Delta, Epsilon, Zeta, Iota, Kappa, and Henry Flad, used in the construction of a channel in the Mississippi River below Cairo were subjected to the following tests, as adopted by the committee on dredges and dredging, of the Mississippi River Commission, dated July 24, 1902:

"(1) Such test[1] shall be made as may be necessary to determine the efficiency of boilers, engines, and sand pumps of each of the dredges. The relative efficiency of the several types of jet pumps, with due consideration of the results required in economical dredging work, should also be carefully determined.

"(2) As a basis for determining the mechanical efficiency of engines and pumps under working load, it is necessary to first determine their frictional horse-power when running at normal speed without load.

"(3) The pump tests shall be made by pumping water with the intake submerged to the normal depth and the pump running at normal speed, and also at known speeds both higher and lower than the normal, in order to ascertain the effect of variations in speed.

"(4) In order to ascertain, as far as practicable, the effect of the form of suction head, tests shall be made both with and without the suction head, where these are so attached as to be readily removable.

"(5) Each test shall embrace the determination of the indicated horse-power of engines, the number of revolutions of pump per minute, the velocity of flow in suction and discharge pipes, the suction and discharge pressures.

"(6) In addition to the pressure gages now in use, mercury manometers should be attached to suction and discharge pipes near pump for the accurate determination of suction and discharge pressures.

"(7) The velocity of flow in suction and discharge pipe shall be carefully measured, and their determinations made at several points in the cross-section of discharge pipe, so as to determine whether or not the whole of the discharge section is effective under normal pumping conditions. This test can, however, only be made when pumping sand, but it would not interfere materially with the regular field work, if done when dredges

[1] From Annual Report of the War Department, 1903. Vol 13.

are in operation. Pitot's tubes are recommended for use in making velocity observations.

"(8) The loss of head due to friction in the discharge pipe shall be determined. It is also desirable to carry this investigation further, if found practicable, so as to include the effect of curved sections, rough joints, etc.

"(9) It is also desirable to measure, as far as practicable, the relative efficiency of the double and single intake to ascertain whether the flow of two columns of water from opposite directions and meeting at the center of the pump tends to materially reduce the efficiency.

"(10) In conducting the above required investigation, other lines of inquiry will doubtless be suggested, and if they promise results of value they should be followed up.

"(11) When the required observations have been completed, they shall be carefully studied and compared, with a view to determine the most efficient type of engine and pump now in use, and how the best of these could be improved upon in future construction.

"(12) The results of the above investigations shall be embodied in a report giving in detail the type and form of boilers, engines, and pumps examined, and the observations made in each case, with a summary showing from the results which type or combination of types is the most efficient and best for the conditions met with in the Mississippi River.

"(13) It is intended that the investigations and experiments called for above will be made at such times as the dredges are not otherwise employed, as when lying at the bank waiting for suitable stage of water or at the close of the coming dredge season before being laid up for the winter. It is, therefore, desirable to have such preparations made in the way of instruments and measuring appliances and attachments as may be deemed necessary before going into the field."

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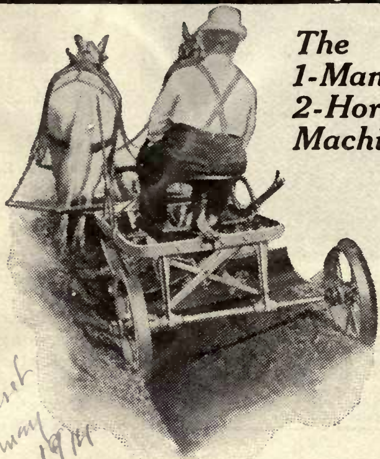

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